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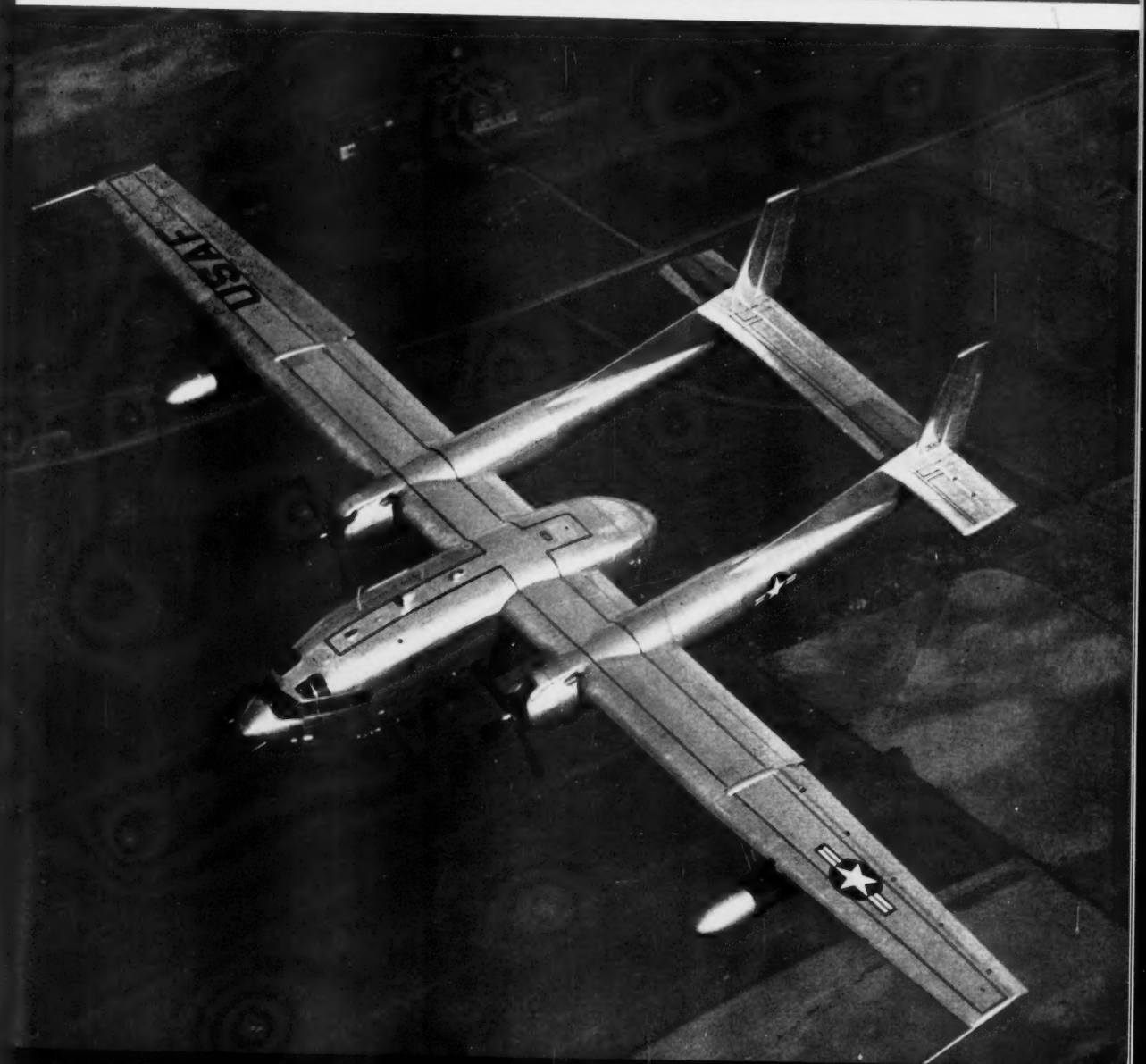
AERONAUTICAL ENGINEERING REVIEW

SEPTEMBER 1952



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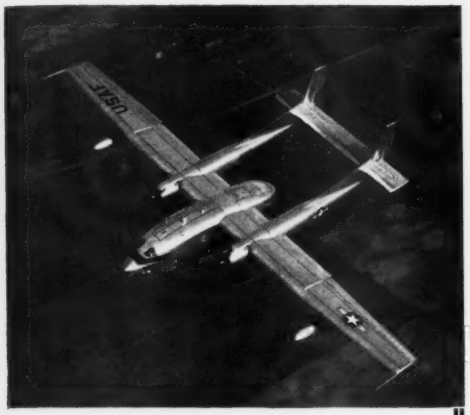

Cover—This flight photo of the new C-119H Flying Boxcar medium troop and cargo transport shows some of its more apparent modifications, i.e., the newly redesigned wing with its 148-ft. span, the larger empennage, and the application of external fuel pods under the wings. This latest addition to the Flying Boxcar series was built by the Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation, and is powered with two Wright R-3350-30W 3,500-hp. compound engines.

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SUBSCRIPTION RATES

Aeronautical Engineering Review: United States and possessions, 1 year, $3.00; single copies, $0.50. Foreign countries including Canada (American Currency Rates), 1 year, $3.50; single copies, $0.50.

Entered as second-class matter at the Post Office, Easton, Pa., April 29, 1942. Acceptance for mailing at a Special Rate of Postage as provided for in the Act of August 24, 1912.

Publication Office: 20th & Northampton Streets, Easton, Pa.

Editorial Office: 2 East 64th Street, New York 21, N.Y. Notices of change of address should be sent to the Institute at least 30 days prior to actual change of address.

Statements and opinions expressed in the Aeronautical Engineering Review are to be understood as individual expressions and not those of the Institute.

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AERONAUTICAL ENGINEERING REVIEW

Vol. 11 **SEPTEMBER, 1952** **No. 9**

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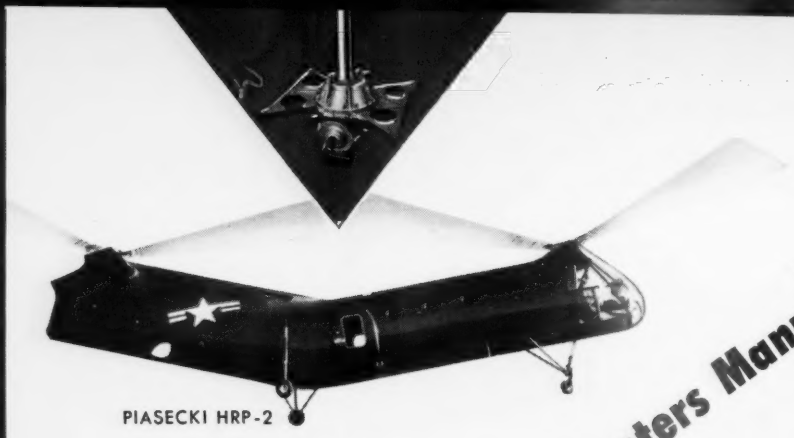
Published Monthly by the Institute of the Aeronautical Sciences, Inc.

Transmissions on Piasecki Helicopters Manufactured by Foote Bros.



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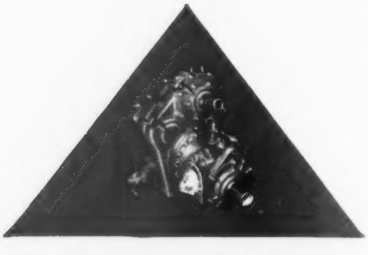

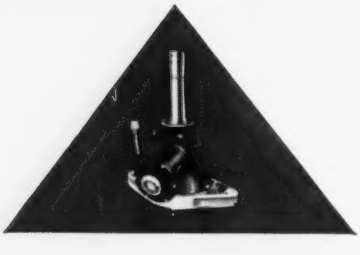

Flying from Navy ships, Piasecki Helicopters are performing such vital missions as rescuing downed pilots and developing anti-submarine warfare techniques. U. S. Marines used them to evolve airborne assault tactics. Now the giant Piasecki H-21 Workhorse opens up new possibilities with its longer range and higher load capacity.

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I. A. S. News

A Record of People and Events of Interest to Institute Members

Annual Summer Meeting Largest Yet

More Than 750 I.A.S. Members and Guests Attend Honors Dinner and Technical Sessions

THE 1952 SUMMER MEETING IN LOS ANGELES, July 16–18, brought the biggest turnout of aeronautical savants ever to attend one of these summer gatherings of the Institute. Several innovations, including the breaking-up of the technical sessions to sandwich-in a carrier cruise, may have been a contributing factor. There is a sneaking suspicion, however, that more of the meeting's success may be directly charged to the well-rounded program, the caliber of technical papers presented, and the general overall planning and handling of meeting details. Full credit for this must go to officers and members of the Los Angeles Section under the chairmanship of Allen Puckett and to members of the Program Committee and its enthusiastic chairman, Richard R. Heppe.

▸ **Technical Sessions.**—Eighteen papers, two of which are security-classified, were presented during the five technical sessions on Aerodynamics, Structures, Propulsion, and Design at the Institute's Los Angeles building. Except for those confidential papers presented at the closed Aircraft Design Session, the remainder are scheduled for the earliest possible publication in the REVIEW and the JOURNAL. Preprints of papers immediately available are listed on the Preprint Page of this issue (page 56).

A recap and discussion of the technical sessions, prepared by the chairman of each individual session, will appear in the October issue of the REVIEW.

▸ **Summer Meeting Dinner.**—More than 750 guests packed the Embassy Room of the Hotel Ambassador for the Honors Dinner on July 16. As usual, this was the occasion for presenting the Thurman H. Bane and Octave Chanute awards for outstanding achievements. Presentations of the Bane Award to Henry Seeler and the Chanute Award to John C. Seal were made by I.A.S. President, Wellwood Beall. (Details of these awards and the 1952 recipients were announced in the August REVIEW.)

An added "award" was featured at this year's dinner when I.A.S. Director, S. Paul Johnston, announced receipt from the Royal Aeronautical Society of two beautiful carved-leather plaques—one honoring this year's president, Wellwood E. Beall, and the other carrying the respects of the R.Ae.S. directly to the Institute. Both plaques are now on permanent display in the Institute's Archives in New York.

The principal speech of the evening was delivered by the U.S. Secretary of the Navy, The Honorable Dan A. Kimball. Excerpts from his talk have been published as this month's Guest Editorial and may be found on pages 20, 21, and 54 of this issue.

▸ **Field Trips.**—Through the courtesy of Rear Adm. D. S. Cornwell, Commander, Carrier Division Fifteen, a full day's cruise aboard the Essex-class carrier U.S.S. "Kearsage," under the command of Capt. L. E. French, U.S.N., was arranged for 250 security-cleared I.A.S. members and Corporate Member representatives. This event, which took place on July 17, gave members of the boarding party first-hand information on the operation of carriers and shipboard jet fighters. It also provided one of the most pleasurable highspots of the meeting.

On Friday, July 18, some fifty security-cleared Corporate Member representatives had the privilege of witnessing some missile and aircraft demonstrations at Edwards A.F.B. as guests of Col. J. Stanley Holtnor, Commanding Officer, A.F.F.T.C.

In spite of a tight, jam-packed schedule and the necessity of running the Edwards trip concurrently with Friday's technical sessions, the consensus seems to be that this was one of the best and most profitable meetings ever held on the West Coast.

Toastmaster Wellwood E. Beall
I.A.S. President

Attention Members!

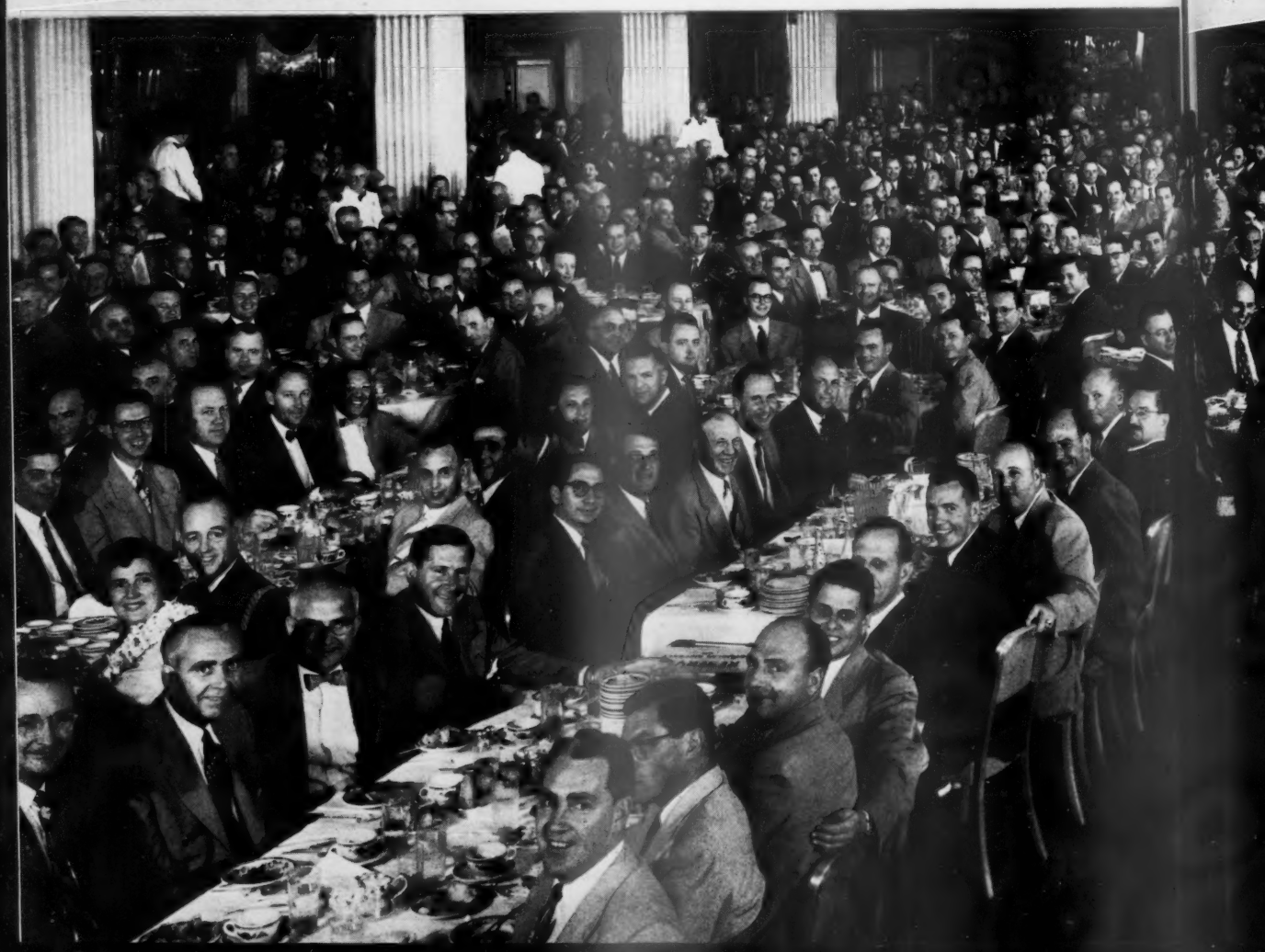
All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review.*

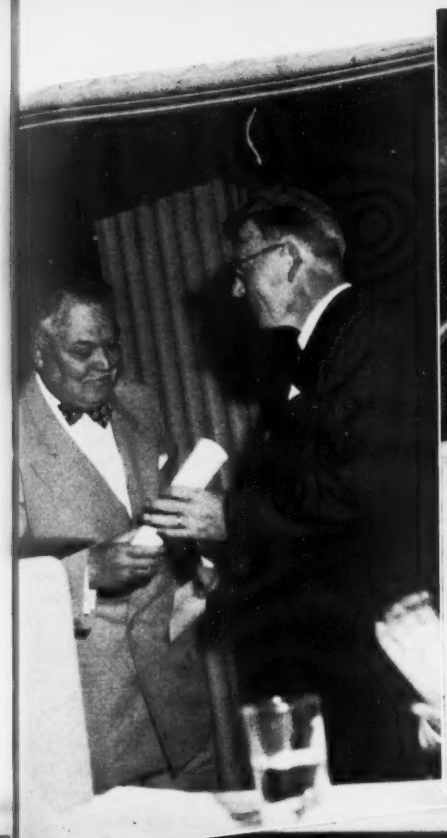
Annual Summer Meeting Dinner

July 16, 1952

Embassy Room
Hotel Ambassador
Los Angeles, Calif.

(Left) The Honorable Dan A. Kimball, principal speaker of the evening, addressing the dinner audience pictured *below.* *(Opposite page, left)* I.A.S. President, Wellwood E. Beall, presents The Thurman H. Bane Award for 1952 to Henry Seeler. *(Center)* S. Paul Johnston, I.A.S. Director, displays the plaques presented to the Institute by the Royal Aeronautical Society. *(Right)* John C. Seal acknowledges receipt of The Octave Chanute Award for 1952.





West Coast Student Conference

The Second Annual West Coast Conference of the I.A.S. Student Branches was held at the I.A.S. Western Headquarters Building in Los Angeles on May 15–17. It was attended by 145 representatives from the University of California at Berkeley, University of California at Los Angeles, Cal-Aero Technical Institute, California Institute of Technology, California State Polytechnic College, Northrop Aeronautical Institute, Oregon State College, University of Southern California, Stanford University, and University of Washington.

Registration for the conference began at 8 a.m. on Thursday, May 15, and continued throughout the day until 5:30 p.m. At the invitation of the Los Angeles Section, the student representatives that evening attended the regular May dinner meeting of the section. The speaker was Capt. N. A. Draim, U.S.N., Bureau of Aeronautics General Representative, Department of the Navy, who spoke on "Personal Observations of Russian Military and Economic Conditions."

Field trips were made on May 16 to local aircraft plants by security-cleared citizens and to local school facilities by noncitizens.

On the third and last day of the conference, May 17, two technical sessions were held. At the morning session, under the Chairmanship of R. Richard Heppe, of Lockheed Aircraft Corporation, five undergraduate student speakers presented papers. The speakers and their papers were: William Sowell, Cal-Aero, "A Method of Light Aircraft Performance Estimation"; V. Keith Putman, Cal Poly, "Interplanetary Travel . . .How, When. . . Why?"; Roy A. Hinchliffe, N.A.I., "A Transonic Propeller of Triangular Plan Form"; William L. Marcy, U.C.L.A., "Canard Aircraft Stability Experiment"; and C. E. Hallum, U.C., Berkeley, "The Hydraulic Analogy of Two-Dimensional Gas Flow."

The afternoon session was devoted to papers presented by five graduate student speakers. Harold W. Adams, of Douglas Aircraft Company, Inc., served as Chairman. E. R. Letsch, U.C.L.A., delivered a paper on "Methods of Solutions for the Laminar Compressible Boundary Layer"; F. S. Sherman, U.C., Berkeley, on "Flat Plate Drag Coefficients in Supersonic and Subsonic Low Density Airflows"; Raymond Chuan, CalTech, on "Low Reynolds Number Trans-Sonic Wind Tunnels"; Donald Hays, Oregon State, on "Stress Distribution About a Square Hole in an Uniaxial Tension Plate"; and Harold Anderson, U.W., on "Deflections of the Cantilever Plate."

Messrs. Heppe and Adams, together with Charles W. Frick, of Ames Aeronautical Laboratory, N.A.C.A., served as a committee of judges to select the undergraduate and graduate speakers who won the first, second, and third prizes for their presentations in the two technical sessions. That evening at the final dinner meeting, Frank R. Seery, who as Conference Chairman had given greetings to the registrants, announced the winners of the two groups. Among the undergraduate speakers, Mr. Sowell won first place with Messrs. Hallum and Putnam winning second and third prizes, respectively. Among the graduate speakers, Mr. Chuan was awarded first prize, and Messrs. Hays and Anderson won second and third prizes, respectively. The first-place prizes consisted of cash honorariums of $50 each along with a congratulatory letter from Dr. Alan E. Puckett. (Dr. Puckett, Chairman of the Los Angeles Section, had expected to preside at the dinner meeting but was unable to be present.) The second and third place awards in each of the two divisions were desk miniatures of current Boeing and North American aircraft.

After the presentation of the awards was completed, Edward H. Heinemann, of Douglas Aircraft Company and an I.A.S. Vice-President, read a paper for Wellwood E. Beall of Boeing Airplane Company and I.A.S. President, who was also unable to attend the conference. Mr. Beall's paper was entitled "The Future of Engineering in Aviation."

The Conference Committee consisted of P. Andre Reiben, of Cal-Aero; Thomas Vrebalovich, of CalTech; Arthur Eck, A. Armand Tolomeo, and Alfred E. Andreoli, of N.A.I.; and Donald E. Lapedes and M. Rubinstein, of U.C.L.A.

Student Conference Speakers: *Shown are eight of the ten undergraduate and graduate student speakers at the Second Annual West Coast Conference of the I.A.S. Student Branches. From left to right, they are: Harold Anderson, University of Washington graduate; F. S. Sherman, University of California graduate; Donald Hays, Oregon State College graduate; V. Keith Putnam, California State Polytechnic College; Roy A. Hinchliffe, Northrop Aeronautical Institute; C. E. Hallum, University of California; William L. Marcy, University of California at Los Angeles; and William Sowell, Cal-Aero Technical Institute. Not shown in this photograph are E. R. Letsch, University of California at Los Angeles, and Raymond Chuan, California Institute of Technology, both graduate students.*

I.A.S. Cosponsors Heavy Forgings and Extrusions Symposium on December 2

A symposium on light-metal heavy forgings and extrusions will be held at the Hotel Statler, New York City, on December 2, 1952, under the joint sponsorship of the American Society of Mechanical Engineers, Institute of the Aeronautical Sciences, American Institute of Mining Engineers, and Society of Automotive Engineers. It is being presented in conjunction with the A.S.M.E.'s regular annual meeting.

The December 2 symposium will include both morning and afternoon sessions, followed by a dinner meeting. The morning session will be opened by J. Carlton Ward, Jr., M.I.A.S., Chairman of the Board, Thompson Industries, Inc., and Aviation Consultant, who will present highlights regarding the development of this joint meeting.

Immediately thereafter, the following papers will be presented:

George W. Papen, M.I.A.S., Lockheed Aircraft Corporation: "Requirements for Large (Light Metal) Forgings and Extrusions in the Aircraft Industry." Dr. Morris Stone, United Engineering and Foundry Company: "The Design and Construction of Large Forging and Extrusion Presses for Light Metals." Thomas L. Fritzlen, Reynolds Metals Company: "Metallurgy and Protection of Suitable Light Metal Ingots for Large Forgings and Extrusions."

Following luncheon, these two additional papers will be delivered: George Motherwell, Wyman Gordon Company: "The Large Forging Press Operation and Its Production Problems." T. F. McCormick, Aluminum Company of America: "The Large Extrusion Press and Its Production Problems."

The Honorable Roswell L. Gilpatric, Under Secretary of the Air Force, has accepted an invitation to speak at the dinner meeting. He will address the assemblage on the subject of "The History of the Inception of the Large Forging and Extrusion Program for the Aircraft Industry, and Its Vital Importance to the National Defense Program for the United States."

The committee in charge of planning the symposium program is composed of the following persons: Co-Chairmen, Robert B. Lea, A.M.I.A.S., of The Sperry Corporation, and Mr. Ward; Secretary, Dr. George Gerard, A.F.I.A.S., of new York University's College of Engineering; A.S.M.E. Representative, O. B. Schier; A.I.M.E. Representative, Dr. T. A. Read, of Columbia University's School of Mines; I.A.S. Representative, Robert R. Dexter, F.I.A.S.; S.A.E. Representative, Dr. William J. O'Donnell, M.I.A.S.; and Public Relations Coordinator, Ken Ellington, of Republic Aviation Corporation. Major John F. Probst was assigned as Air Force Liaison.

Corporate Member Air Carriers Receive Awards

Four I.A.S. Corporate Members were among the 41 U.S. domestic, territorial, and overseas scheduled air lines named on June 26 as winners of the National Safety Council's aviation safety awards for their contributions to safe air transportation in 1951. The Corporate Member air carriers are: American Airlines, Inc.; Eastern Air Lines, Inc.; Trans World Airlines, Inc.; and United Air Lines, Inc.

The span of safe operation and accumulated mileage of these four companies, as compiled from the official records of the Civil Aeronautics Board, are:

Company	Span of Safe Operation Period	Passenger-Miles Without Fatality to End of 1951 or Date of 1951 Accident
American	11-29-49 to 12-31-51	4,675,379,000
Eastern	11-1-49 to 12-31-51	3,100,905,000
Trans World	8-31-50 to 12-31-51	2,540,855,000
United	6-17-48 to 4-28-51	4,143,506,000

Members of the Council's Award Advisory Committee are: Lt. Gen. James H. Doolittle, I.A.S. Honorary Fellow, Founder Member, and Past-President, Vice-President and Director, Shell Oil Company; and Harry F. Guggenheim, I.A.S. Honorary Member, Member, and Founder Member, Partner, Guggenheim Brothers.

1952 Guggenheim Jet Propulsion Fellows

The appointment of 15 new Daniel and Florence Guggenheim Jet Propulsion Fellows was jointly announced on June 27 by Harry F. Guggenheim, H.M.I.A.S., M.I.A.S., President of The Daniel and Florence Guggenheim Foundation; Dr. Harold W. Dodds, President of Princeton University; and Dr. Lee A. DuBridge, President of California Institute of Technology. Seven of the new Guggenheim Fellows will attend the Daniel and Florence Guggenheim Jet Propulsion Center at Princeton, while the remaining eight will study at the Daniel and Florence Guggenheim Jet Propulsion Center at CalTech. These centers were established in 1948.

At Princeton, the fellowships have been granted to: Arnold Brooks, of Lynn, Mass.; Ansel V. Gould, an I.A.S. Student Member, of Maplewood, N.J.; Henry E. Hoercher, of Brooklyn, N.Y.; Richard R. John, of New Rochelle, N.Y.; George B. Milliard, of Kenmore, N.Y.; Edward T. Pitkin, of Putnam, Conn.; and Walter R. Warren, Jr., of Rockaway Beach, N.Y.

The recipients of the CalTech awards are: Odus R. Burggraf, Jr., an I.A.S. Student Member, of Caledonia, Ohio; Donald A. Dooley, of Long Beach; Calif.; Martin Goldsmith, of Piedmont, Calif.; Denver C. Gore, Jr., an I.A.S, Student Member of Portland, Ore.. Frederick Harshbarger, of North Liberty, Iowa; Charles A. Lindley, of Euclid, Ohio; Alphonse P. Peters, of Norwich, Conn.; and Dean A. Rains, of Pasadena, Calif.

The fellowships are awarded for a period of 1 year. However, under certain circumstances, they may be renewed for an additional year. Of the seven Guggenheim Fellowships granted last year, those of the following have been renewed: Arnold Goldburg, of Mahwah, N.J.; Marcel Vinokur, of Long Island City, N.Y.; and George E. Hlavka, of Racine, Wis.

Necrology

William C. Hoff

William Charles Hoff, A.M.I.A.S., died on June 14 of a heart attack at his home in Lake Mohawk, N.J.

Born in Jersey City, N.J., on April 17, 1912, Mr. Hoff was graduated from the Bayonne, N.J., Senior High School in 1930 and from the Industrial Lenders Technical Institute, in Newark, N.J., in 1936. He also attended at various times New York University, Columbia University, and University of Michigan, taking courses in aeronautical engineering and business administration.

During his professional life, Mr. Hoff served primarily as an Aviation Writer and Editor. In 1940, he became Assistant to the General Editor of the American magazine *Aeronautics*. He later served as Associate Editor for *Flying* and *Popular Aviation* magazines, after which he entered the technical manual publication business. For the past several years, he was Vice-President of Techcraft, Inc., publishers of aircraft and engine technical manuals.

Mr. Hoff is survived by his wife, the former Rita Adele Gilbertson, and their two children, William C., Jr., aged 8, and Barbara, aged 6.

News of Members

▸ **Dr. Allen V. Astin** (H.M.), Director, National Bureau of Standards, was named an N.A.C.A. member.

▸ **M. G. (Dan) Beard** (M.), Chief Engineer, American Airlines, Inc., was awarded a Certificate of Merit by the Air Force Association at its annual convention banquet held on last May 24. Mr. Beard, who at that

(*Continued on page 58*)

Guest Editorial

"Is There an Idea in the House—?"

The Address Given at the Institute's Annual Summer Meeting Dinner at the Hotel Ambassador in Los Angeles on July 16

by

The Honorable
DAN A. KIMBALL
Secretary of the Navy

"I always feel at home among the aviation people, because we speak the same language. The appeal of aviation is somewhat the same as the appeal which draws men to explore unmapped lands or crawl underground to see what there is in a dark cave.

"This appeal has made it relatively easy to attract into aviation restless, intellectually aggressive men. It has also made it relatively easy to attract and hold scientists who are gifted with ability and imagination —and unquenchable curiosity.

"In the past, the problems we thought were difficult, if not insurmountable, now appear to be simple and easy. That is the priceless thing about hindsight. There can be no question but that our present problems are more complex. There are many in the industry who feel that progress can only be made through major efforts by platoons of people. They hold that the individual can only become hopelessly bogged down in the new complexities.

"I for one won't buy that point of view. I think the attitude is defeatist, and I think that, if we knuckle under to it, it is in effect a surrender. It makes no difference how complex the problem may have been. I think you will find that the initial steps toward its solution have been taken as the result of an ideal in some restless mind. We are going to have to encourage these minds, but I'll get to that later on.

"Let's first take a look at the present situation in aeronautical science and in the industry which it serves.

"In the first place, aviation is in an enviable position. There is still the challenge of the unknown, which is translated into the driving force which leads to higher and higher accomplishment. We have built a great store of ideas which research and later development have not yet fully exploited. Aviation has exploited them further than probably any other branch of science, but there is still a long, long way to go.

"Exploitation is proceeding at a rapid pace. *All* industry today is following the example of aviation. The examples are many, and I cite only as instances: accurate structural design; light-alloy metallurgy; special-alloy metallurgy; aerodynamics and hydrodynamics; automatic control mechanisms; and last, but certainly not least, human engineering.

"A few years ago, it was considered a wisecrack to say that, if aviation proceeded much further in airplane design, they would have to stop somewhere along the line and redesign the pilots. Well, since that time

man has flown through the sonic barrier a good many times, and today this speed point, which was once considered to be a barrier, is merely a spot where you change the decimal point on the Mach.

"Human engineering research has shown that, with certain mechanical aids, man cannot only fly and fight these high-speed aircraft but that, if disabled, he has a fair chance of getting out of the plane alive and living to tell his children about it. We have designed equipment which enables pilots to withstand quite a few more g's than was ever believed to be possible. Most of you here will certainly remember that a 9-g pull-out was a toss up whether the wings stayed on the airplane or not, and, if they did, would the pilot black out.

"The solutions to these problems are the result of painstaking research, hard work in the development field, and generous ladlesfull of the punch that keeps a man curious, restless, and aggressive.

"Aeronautics still has a fair stockpile of tricks. It is not important if one of these tricks is lifted bodily by some other branch of industry. It is not important if a plan for a new discovery is made simultaneously by several people. The important thing is that aeronautical scientists and the industry they serve quickly realize what is taking place and go out and dig up some new trick. I think, however, that we are approaching the day when industry in this country is going to have to make longer-range investments in the development of brains.

"It is all very well to compete for the best trained men who are coming out of our engineering schools annually, and it is all very well to stimulate young men and women to enter the engineering field. That, as I say, is fine, but it is not enough. I think we need to devise, in addition to the measures we are already taking, some way in which our very best brains can be allowed to enjoy an open-end commitment in the research field. To do this, we need first of all to find ways and provide means for ferreting out these best brains. Then, when we have found them, relieve them of the economic necessity of earning a living.

"The idea I suggest I know is not an easy one to implement. But we are going to have to do something about it if we are going to survive today's fierce scientific competition.

"I would like to see a committee of some of our best brains in the aeronautical sciences get together and study this problem. They ought to consult with the best minds in other fields of scientific research and then draft a plan. Once a plan has been framed, the rest is up to you gentlemen. You cannot be expected to provide all the money which will be needed to put such a plan into operation, but I feel reasonably certain that, if you come up with a workable plan, you will be able to interest one or more of the great foundations in helping you out.

"Some such plan as this is needed if we are going to provide for this nation's future scientific needs. The need in aeronautics has always been for new and sometimes novel ideas. The industry has grown up on this sort of diet, and it must continue that diet to maintain its strength and keep on being successful.

"In the future, it will not be enough merely to build airplanes which are a little bit better or a little bit bigger than those of the present. I know we are all agreed that we must have the very best. But we are not agreed on how we are going to get it.

"How can we get the best airplanes? There is no simple answer to that question. In the final analysis we know that the real basis of superiority is someone's advanced thinking. It is based on best thinking and new ideas and lots of both. Such thinking and planning is a vital factor to the aircraft industry, and, more importantly, it is vital to our national defense.

"The capabilities of the aviation industry have provided us with many advances since the end of the second war. All of our first-line combat aircraft are new since that war. We need to continue to design and improve on existing designs because, as I say, it is necessary to our defense. On the strength and capability of our defense, rests our future as a free nation in a free world.

"Scientists and engineers have a great responsibility in helping to make this future a reality—not only aeronautical engineers and scientists but engineering in its broadest concepts. Not so many months ago, I spoke to a group of naval engineers and architects. I took them somewhat to task—I hope in a kindly fashion—because they had not, up until that time, made the progress I think we have a right to expect in the field of marine propulsion.

"Not long after that, I spoke to a group of shipping people and said much the same thing. I pointed out that we very nearly lost two world wars because we almost lost the battle for command of the seas. It cost us money and millions of tons of shipping to learn that slow freight was a short cut to a slow death. I feel very strongly, and I told them in the strongest words I know that we must never again allow ourselves to be put in the position of supplying a war with 9-knot convoys.

"I am thankful that our aviation industry has come much further in maritime shipping in the years since the second war, but I do not see around me anywhere any evidence which would entitle anyone in any industry to be smug or self-satisfied.

(*Continued on page 54*)

A Meteorological Analysis of Reports of Turbulence Encountered by Aircraft in Clear Air*

CONRAD P. MOOK†

U.S. Weather Bureau Forecast Center, Washington National Airport

Introduction

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Application of George's rule, in which he implied that the difference of the two components was an indicator of the lifting force of the front, implied turbulence, though, at that time, it also appeared that the cause of the jolt might be associated with a rapid change in air speed accompanying the passage of the aircraft through the front.[3]

However, it was also true that the Richardson Criterion, when adjusted in accordance with the suggestion of Petterssen and Swinbank,[4] permitted a situation wherein atmospheric turbulence, once established, was likely to be increasing.

NACA - U. S. Weather Bureau
CLEAR AIR TURBULENCE REPORT

Form Approved Budget Bureau No. 41-R1327
WB 611-2

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① Date _____

② Airplane Type _____

③ Time occurred _____ a.m. / p.m. local standard time

④ Location _____ miles in _____ direction
from _____ (landmark)
or _____ lat. _____ long.

⑤ Indicated altitude: _____ ft.
altimeter setting _____ inches Hg.

⑥ Indicated airspeed: _____ mph / knots

⑦ Estimate of maximum intensity (check one):
☐ slight (perceptible)
☐ moderate (difficulty walking)
☐ severe (objects thrown around cabin)

⑧ Length of time in turbulence: _____ min.

⑨ If climbing or descending,
Vertical extent of turbulence _____ ft.

Remarks: (Describe characteristics of turbulence--choppy, hard jolts, heavy drafts, continuous or intermittent, etc.; describe airplane reactions--wallowing, uncontrolled roll, momentary upsets, etc.; describe evasive action--changes in altitude, direction and airspeed, etc.; if there are any clouds in vicinity, note types and estimated distance.)

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FIG. 1. The N.A.C.A.-Weather Bureau Clear Air Turbulence Questionnaire.

Presented at the Meteorology Session (Joint Session with the American Meteorological Society), Twentieth Annual Meeting, I.A.S., New York, January 28–February 1, 1952.

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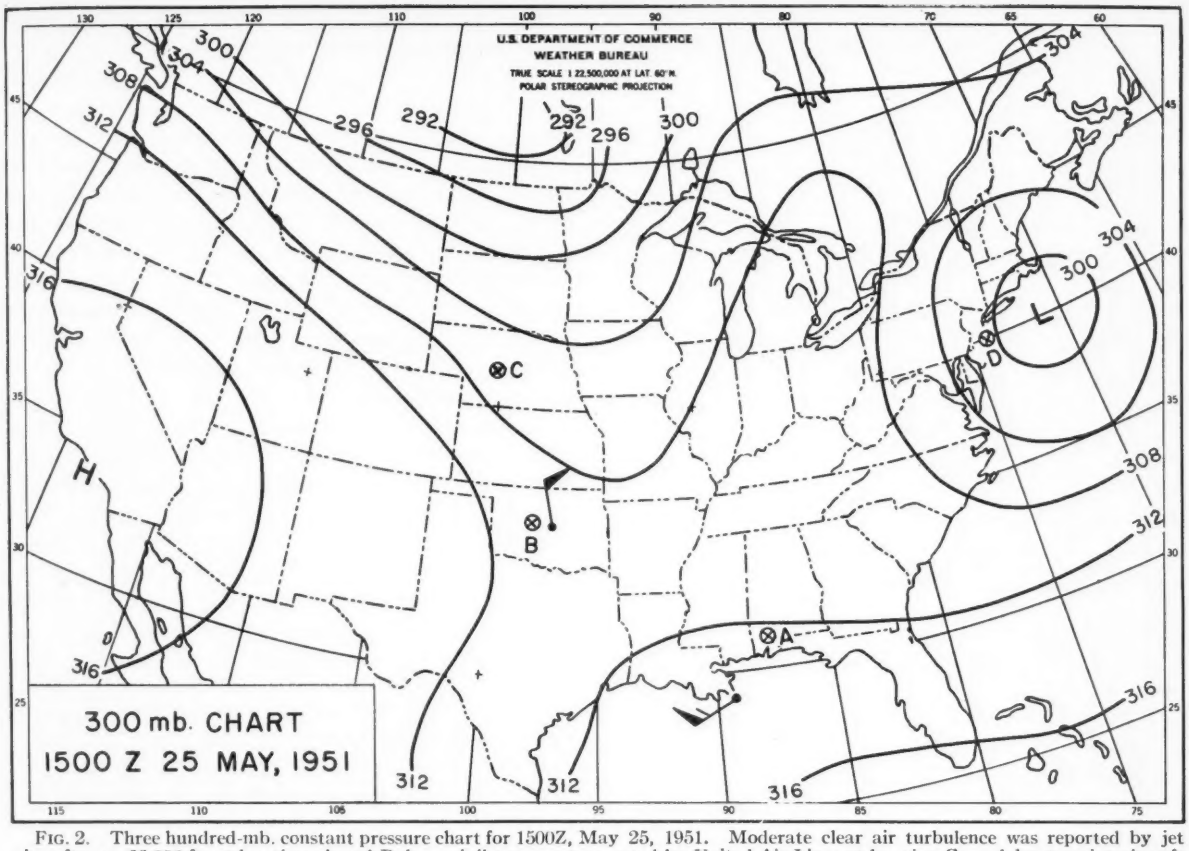

FIG. 2. Three hundred-mb. constant pressure chart for 1500Z, May 25, 1951. Moderate clear air turbulence was reported by jet aircraft near 26,000 ft. at locations A and B, by a civil transport operated by United Air Lines at location C, and by two jet aircraft at 35,000 ft. at location D. (C and D are associated with horizontal shear, which can be seen by inspection of charts for those levels—not illustrated.)

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Fig. 1 illustrates the postcard-type questionnaire by means of which military and civil air-line pilots were asked to report on turbulence encountered in clear air above 10,000 ft. in the case of the air lines and above 25,000 ft. when encountered by military aircraft (except of course instances occurring within 5,000 ft. of mountains).

In all, 241 separate replies were received during the year 1951, eleven of which reported instances of severe turbulence in clear air. Except for some instances reported near thunderstorms or mountains or over hot deserts in summer, most of the data thus far examined seem not to disagree with the recent conclusions of Hislop,[7] Bannon,[8] and others[5]—namely, wind shear is in some way associated with the high-level turbulence encountered by aircraft in clear air.

Fig. 2 illustrates the weather map for approximately 30,000 ft. (actually, it is the 300-mb. constant pressure chart that is normally drawn in lieu of the 30,000-ft. chart) for 10 a.m. EST of May 25, 1951. Near the time for which this chart was constructed, there were two reports of moderate clear air turbulence at about 26,000 ft. at two widely separated points on the map. Fortunately, we have upper wind observations relatively near both instances shown here in Figs. 3 and 4,

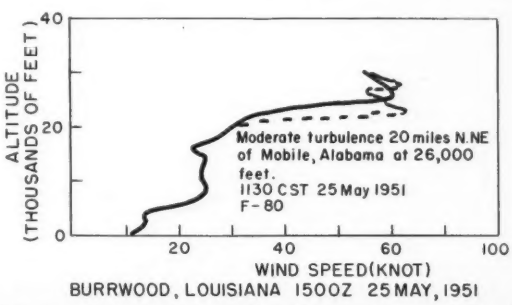

FIG. 3. Upper wind observation, Burrwood, La., 1500Z, May 25, 1951. (Dashed curve in this and other similar illustrations shows data prior to coding for teletype writer transmission.)

Guest Editorial

"Is There an Idea in the House—?"

The Address Given at the Institute's Annual Summer Meeting Dinner at the Hotel Ambassador in Los Angeles on July 16

by

The Honorable
DAN A. KIMBALL
Secretary of the Navy

"I always feel at home among the aviation people, because we speak the same language. The appeal of aviation is somewhat the same as the appeal which draws men to explore unmapped lands or crawl underground to see what there is in a dark cave.

"This appeal has made it relatively easy to attract into aviation restless, intellectually aggressive men. It has also made it relatively easy to attract and hold scientists who are gifted with ability and imagination —and unquenchable curiosity.

"In the past, the problems we thought were difficult, if not insurmountable, now appear to be simple and easy. That is the priceless thing about hindsight. There can be no question but that our present problems are more complex. There are many in the industry who feel that progress can only be made through major efforts by platoons of people. They hold that the individual can only become hopelessly bogged down in the new complexities.

"I for one won't buy that point of view. I think the attitude is defeatist, and I think that, if we knuckle under to it, it is in effect a surrender. It makes no difference how complex the problem may have been. I think you will find that the initial steps toward its solution have been taken as the result of an ideal in some restless mind. We are going to have to encourage these minds, but I'll get to that later on.

"Let's first take a look at the present situation in aeronautical science and in the industry which it serves.

"In the first place, aviation is in an enviable position. There is still the challenge of the unknown, which is translated into the driving force which leads to higher and higher accomplishment. We have built a great store of ideas which research and later development have not yet fully exploited. Aviation has exploited them further than probably any other branch of science, but there is still a long, long way to go.

"Exploitation is proceeding at a rapid pace. *All* industry today is following the example of aviation. The examples are many, and I cite only as instances: accurate structural design; light-alloy metallurgy; special-alloy metallurgy; aerodynamics and hydrodynamics; automatic control mechanisms; and last, but certainly not least, human engineering.

"A few years ago, it was considered a wisecrack to say that, if aviation proceeded much further in airplane design, they would have to stop somewhere along the line and redesign the pilots. Well, since that time

man has flown through the sonic barrier a good many times, and today this speed point, which was once considered to be a barrier, is merely a spot where you change the decimal point on the Mach.

"Human engineering research has shown that, with certain mechanical aids, man cannot only fly and fight these high-speed aircraft but that, if disabled, he has a fair chance of getting out of the plane alive and living to tell his children about it. We have designed equipment which enables pilots to withstand quite a few more *g*'s than was ever believed to be possible. Most of you here will certainly remember that a 9-*g* pull-out was a toss up whether the wings stayed on the airplane or not, and, if they did, would the pilot black out.

"The solutions to these problems are the result of painstaking research, hard work in the development field, and generous ladlesfull of the punch that keeps a man curious, restless, and aggressive.

"Aeronautics still has a fair stockpile of tricks. It is not important if one of these tricks is lifted bodily by some other branch of industry. It is not important if a plan for a new discovery is made simultaneously by several people. The important thing is that aeronautical scientists and the industry they serve quickly realize what is taking place and go out and dig up some new trick. I think, however, that we are approaching the day when industry in this country is going to have to make longer-range investments in the development of brains.

"It is all very well to compete for the best trained men who are coming out of our engineering schools annually, and it is all very well to stimulate young men and women to enter the engineering field. That, as I say, is fine, but it is not enough. I think we need to devise, in addition to the measures we are already taking, some way in which our very best brains can be allowed to enjoy an open-end commitment in the research field. To do this, we need first of all to find ways and provide means for ferreting out these best brains. Then, when we have found them, relieve them of the economic necessity of earning a living.

"The idea I suggest I know is not an easy one to implement. But we are going to have to do something about it if we are going to survive today's fierce scientific competition.

"I would like to see a committee of some of our best brains in the aeronautical sciences get together and study this problem. They ought to consult with the best minds in other fields of scientific research and then draft a plan. Once a plan has been framed, the rest is up to you gentlemen. You cannot be expected to provide all the money which will be needed to put such a plan into operation, but I feel reasonably certain that, if you come up with a workable plan, you will be able to interest one or more of the great foundations in helping you out.

"Some such plan as this is needed if we are going to provide for this nation's future scientific needs. The need in aeronautics has always been for new and sometimes novel ideas. The industry has grown up on this sort of diet, and it must continue that diet to maintain its strength and keep on being successful.

"In the future, it will not be enough merely to build airplanes which are a little bit better or a little bit bigger than those of the present. I know we are all agreed that we must have the very best. But we are not agreed on how we are going to get it.

"How can we get the best airplanes? There is no simple answer to that question. In the final analysis we know that the real basis of superiority, is someone's advanced thinking. It is based on best thinking and new ideas and lots of both. Such thinking and planning is a vital factor to the aircraft industry, and, more importantly, it is vital to our national defense.

"The capabilities of the aviation industry have provided us with many advances since the end of the second war. All of our first-line combat aircraft are new since that war. We need to continue to design and improve on existing designs because, as I say, it is necessary to our defense. On the strength and capability of our defense, rests our future as a free nation in a free world.

"Scientists and engineers have a great responsibility in helping to make this future a reality—not only aeronautical engineers and scientists but engineering in its broadest concepts. Not so many months ago, I spoke to a group of naval engineers and architects. I took them somewhat to task—I hope in a kindly fashion—because they had not, up until that time, made the progress I think we have a right to expect in the field of marine propulsion.

"Not long after that, I spoke to a group of shipping people and said much the same thing. I pointed out that we very nearly lost two world wars because we almost lost the battle for command of the seas. It cost us money and millions of tons of shipping to learn that slow freight was a short cut to a slow death. I feel very strongly, and I told them in the strongest words I know that we must never again allow ourselves to be put in the position of supplying a war with 9-knot convoys.

"I am thankful that our aviation industry has come much further in maritime shipping in the years since the second war, but I do not see around me anywhere any evidence which would entitle anyone in any industry to be smug or self-satisfied.

(*Continued on page 54*)

A Meteorological Analysis of Reports of Turbulence Encountered by Aircraft in Clear Air*

CONRAD P. MOOK†

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① Date _____

② Airplane Type _____

③ Time occurred _____ a.m. / p.m. local standard time

④ Location _____ miles in _____ direction
from _____ (landmark)
or _____ lat. _____ long.

⑤ Indicated altitude: _____ ft.
altimeter setting _____ inches Hg.

⑥ Indicated airspeed: _____ mph / knots

⑦ Estimate of maximum intensity (check one):
☐ slight (perceptible)
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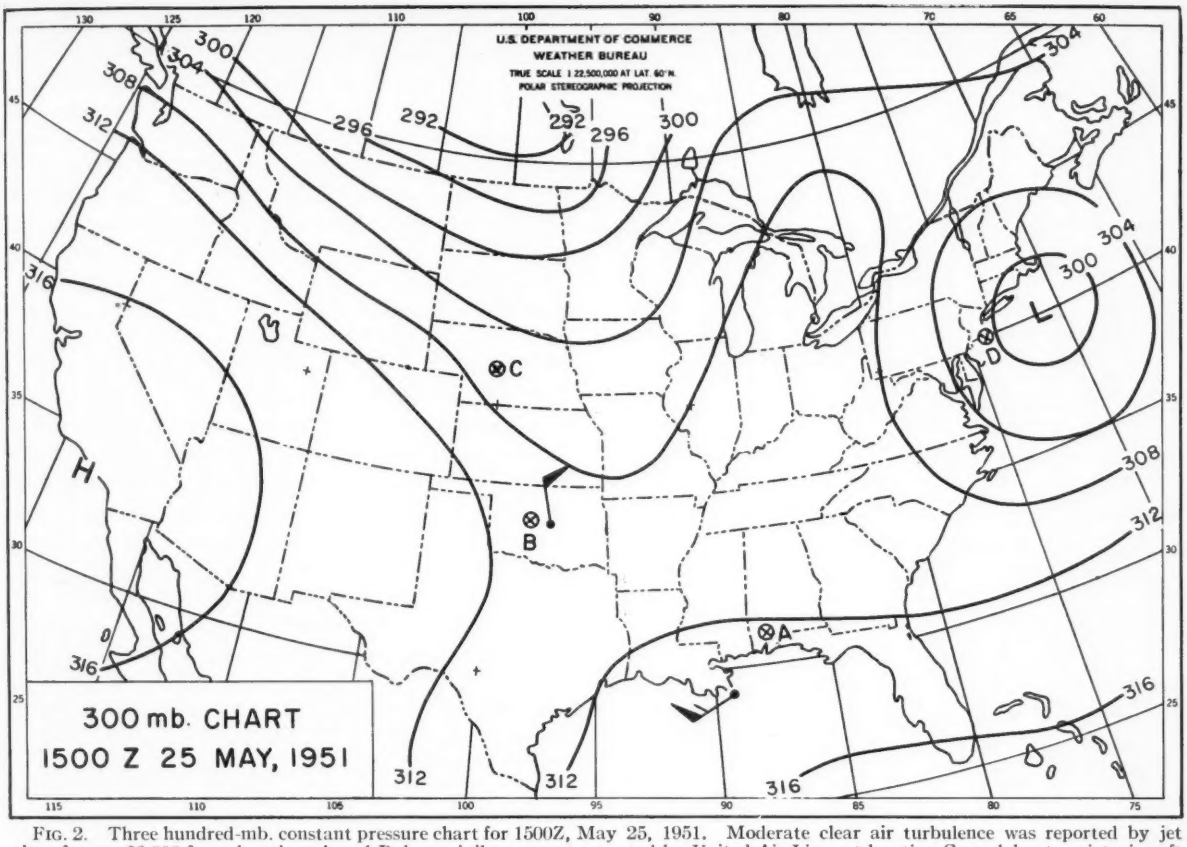

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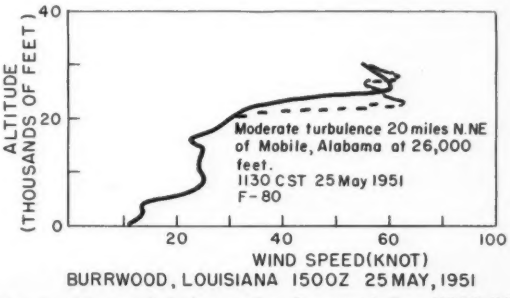

FIG. 3. Upper wind observation, Burrwood, La., 1500Z, May 25, 1951. (Dashed curve in this and other similar illustrations shows data prior to coding for teletype writer transmission.)

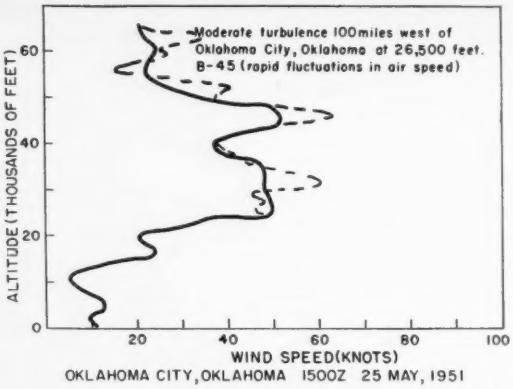
Moderate turbulence 100miles west of Oklahoma City, Oklahoma at 26,500 feet. B-45 (rapid fluctuations in air speed)
ALTITUDE (THOUSANDS OF FEET)
WIND SPEED(KNOTS)
OKLAHOMA CITY, OKLAHOMA 1500Z 25 MAY, 1951

FIG. 4. Upper wind observation, Oklahoma City, 1500Z, May 25, 1951.

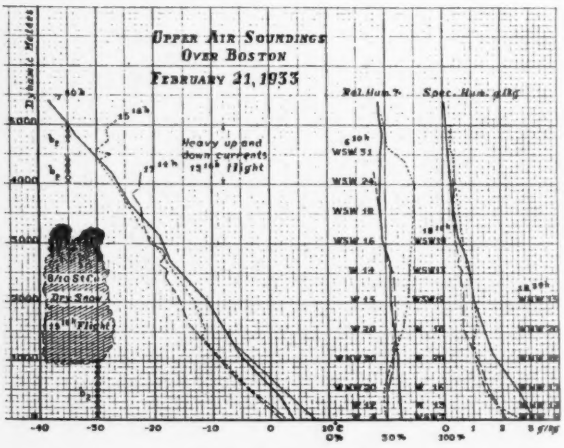

FIG. 5. Upper air sounding over Boston, February 21, 1933 (after Namias).

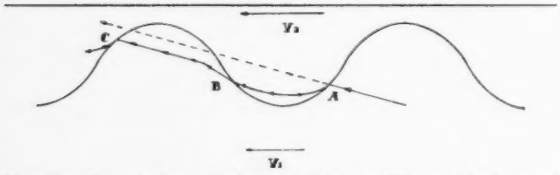

FIG. 6. Lange's hypothesis regarding possible rapid air-speed fluctuations in a shear zone.

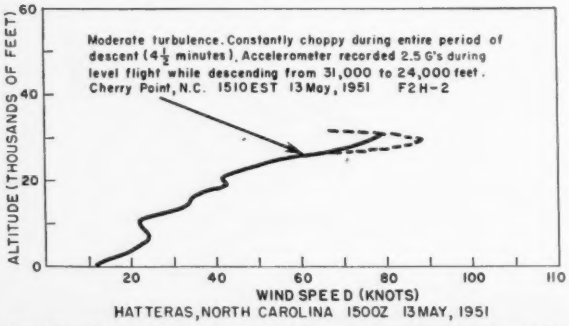
Moderate turbulence. Constantly choppy during entire period of descent (4½ minutes). Accelerometer recorded 2.5 G's during level flight while descending from 31,000 to 24,000 feet. Cherry Point, N.C. 1510EST 13 May, 1951 F2H-2
ALTITUDE (THOUSANDS OF FEET)
WIND SPEED (KNOTS)
HATTERAS, NORTH CAROLINA 1500Z 13 MAY, 1951

FIG. 7. Upper wind observation, Hatteras, N. C., May 13, 1951.

and one can see that in both considerable vertical wind shear was present.

In instances of this kind which have been reported over Europe, the meteorological explanation that has been advocated by both Hislop and Bannon is that Richardson's Criterion for increasing turbulence has been satisfied—namely, the energy developed by the shearing stresses in the atmosphere is sufficient to outweigh the stabilizing effect of the vertical temperature distribution. However, by invoking this criterion, one does not begin to explain the magnitude of the turbulence nor the connection between aircraft turbulence and horizontal wind shear as reported by Harrison and Bannon.*

Returning now to the possibility mentioned earlier, that changes in lift sufficient to reflect bumpiness in the aircraft might result from one or more rapid changes in horizontal air speed, it is necessary to visualize the process as it might occur in regions of vertical shear. Although it was stated earlier in this report that as late as early 1949 only one well-documented case of severe clear air turbulence was available for study, it now appears that a description of an instance of turbulence to a lesser degree which occurred in 1933 was published by Namias.[9] In Fig. 5 is pictured an upper air sounding showing the regions where the aircraft making the soundings unexpectedly encountered bumpiness in clear air above the clouds. Namias accompanied this chart with another, shown in Fig. 6, which he used to illustrate a tentative explanation of the phenomenon that had been supplied to him by one of his colleagues at Massachusetts Institute of Technology, Dr. K. O. Lange. Lange visualized some sort of gravity wave in the subsidence inversion that Namias was describing in his paper. The aircraft, while flying through such waves in the shearing zone, would encounter varying wind speeds. Assuming then that the aircraft, because of its forward momentum, maintained a relatively constant ground speed, the aircraft would undergo rapid changes in air speed which would, he thought, produce changes in lift sufficient to cause the observed bumpiness.†

Such an explanation might also account for the severe turbulence that was reported in a warm front shearing zone near Newfoundland by Baughman.[10] Stone[11] has postulated the existence of waves in warm frontal surfaces of the kind described by Lange, and it has been the author's experience that regular wave-like patterns are sometimes evident in warm frontal precipitation patterns as revealed by radar. Nevertheless, such an explanation of shear zone bumpiness does not find much support in the field of aerodynamics. For example, Hislop[7] has presented some excellent

* Just before going to press, the author learned of Arakawa's discussion[13] of turbulence as associated with horizontal shear in tropical cyclones. This article explains how Richardson's Criterion *is* applicable for horizontal shear.

† See also Humphreys, W. J., *Physics of the Air*, 3rd Ed., pp. 231–234, 239; McGraw-Hill Book Company, New York and London, 1940.

reasons why such an effect should be negligible, and they can be summed up in his quotation of a well-known principle in aerodynamics wherein it is stated that horizontal variations in wind speed have but one-fourth of the effect of vertical gusts of the same magnitude in producing changes in lift.

Hislop then proceeds to show how excessively large the shear must be to produce the observed changes in lift. However, this type of analysis neglects to suggest that the movement of the aircraft, itself, may have an important bearing on its ambient wind environment, as shown in Fig. 7, wherein one easily visualizes the rapidity with which the wind can change while climbing or descending. Furthermore, meteorologists have not yet developed an adequate means of indicating the presence of shear in the vertical of the magnitude which Hislop says must be necessary in order to invoke Lange's explanation of high-altitude bumpiness in clear air.

However, we must agree with Hislop to the extent that air in the vicinity of such waves would have a varying component in the vertical which would necessarily play a part in the production of changes in lift, even without a breakdown of the flow into turbulent eddies.*

Along with Fig. 8 are shown some other vertical wind soundings taken at or near the time and position of the report of clear air turbulence (Figs. 8, 9, and 10). Temperature soundings are not shown because (a) they are not made as frequently in either time or space as are wind soundings and (b) there is some indication in the data on several instances, reported by Bannon as having occurred in November, 1950, that severe turbulence can occur when the shear in the vertical is greater than 5 knots per 1,000 ft., regardless of the vertical temperature distribution. However, Bannon[8] associates these variations in shear with variations in turbulence only after combining the shear with the lapse rate to form the Richardson Criterion. Examination of his data, however, does not suggest that any importance can be attached to variations in lapse rate. Perhaps then the Richardson Criterion is not applicable at high levels, or the mechanism producing the bumps in the shear zone is not so much atmospheric turbulence as bumpiness produced in the manner envisaged by Lange. Thus, we can tentatively conclude that bumpiness will be encountered when the vertical shear is sufficient, regardless of the lapse rate of temperature.

The Structure of Bumpiness as Related to the Jet Stream

Jet streams in the atmosphere have been variously defined, but they are essentially narrow, shallow, rapidly moving streams of air which, for simplicity, can be pictured as circling the earth at a height of around

* It should be pointed out here that any references to laminar or turbulent air motion in this report do not refer to the flow around the airfoil but rather to conditions in the free atmosphere. The point being discussed in this report is whether atmospheric turbulence is necessarily associated with aircraft "bumpiness."

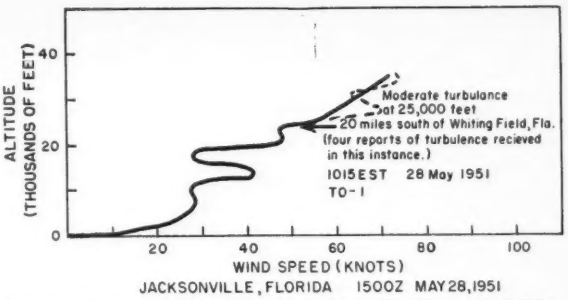

FIG. 8. Upper wind observation, Jacksonville, Fla., 1500Z, May 28, 1951.

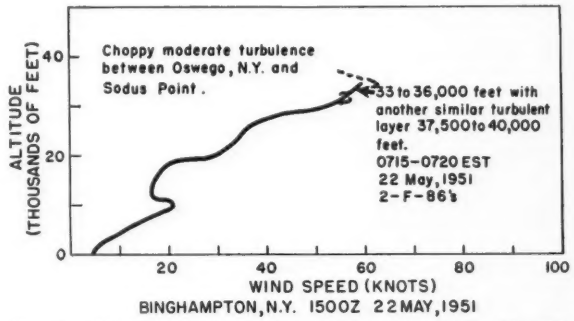

FIG. 9. Upper wind observation, Binghampton, N.Y., May 22, 1951.

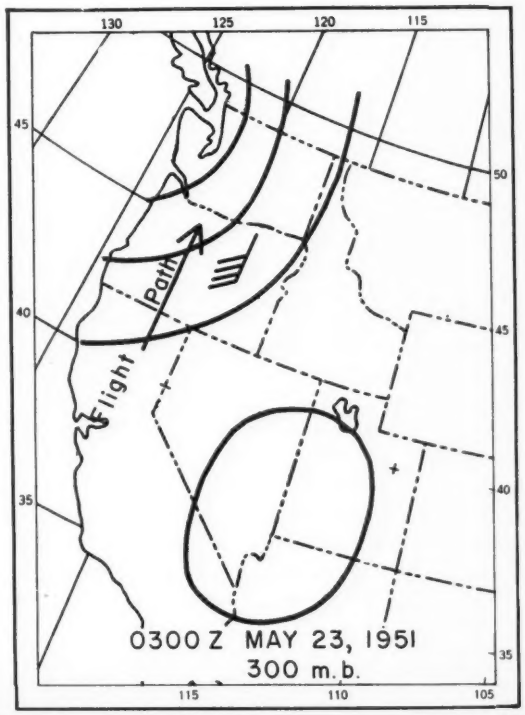

FIG. 10. Three hundred-mb. constant pressure chart, 1500Z, May 23, 1951.

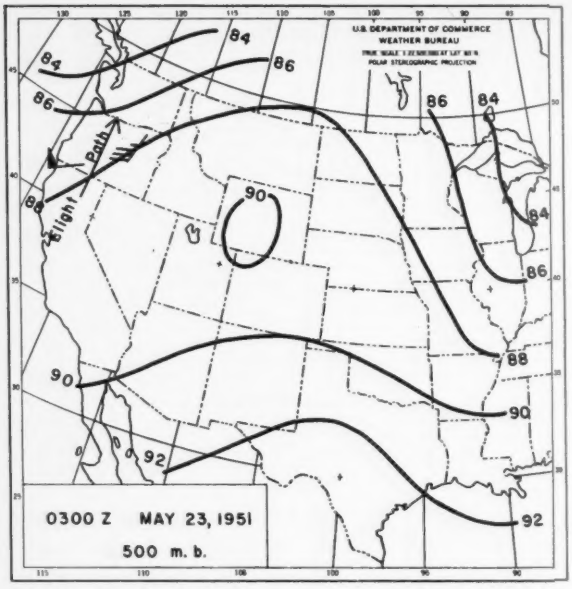

FIG. 11. Five hundred-mb. constant pressure chart, 1500Z, May 23, 1951.

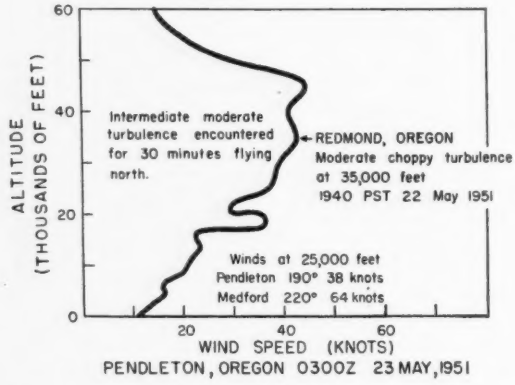

FIG. 12. Upper wind observation, Pendleton, Ore., 1500Z, May 23, 1951.

30,000 ft. A pilot flying into a jet stream from below might find that a 50-knot westerly wind had increased to 80 to 100 knots in a matter of a few thousand feet. Upon continuing to climb, he might find that the westerly wind had fallen back to 50 knots as rapidly as it had been found to increase while climbing into the jet stream.

The picture, which is now emerging regarding the turbulence to be found in the vicinity of the jet stream (cf. Bannon[12]), is that of bumpiness in the zone wherein the shear between the high-speed air and the slower moving current is most marked. Whether the heading and rate of climb of the aircraft are factors tending to affect the amount of turbulence encountered is yet to be determined, and pilots are now being asked to supply this information, although there is increasing indication that some of the most severe turbulence is found while climbing or descending or, if in horizontal flight, in regions of rapidly changing winds. If this picture is correct and the rapidly moving current is more or less homogeneous with respect to the high-speed winds that are found within it, flying within the jet stream, at least in the same direction as the wind, should be smooth. Such a model then suggests the evasive tactics to be used not only to get out of the high-level clear air turbulence (climbing or descending) but also to get out of or stay within the jet stream, whichever may be desired for navigational purposes.

An Example of Turbulence not Associated with a Jet Stream

As mentioned earlier in this report, not all high-level turbulence is associated with jet streams. The coincidence between the two phenomena is believed to be associated with the marked wind shears and high wind speeds which are associated with jet streams, and thus regions of marked wind shear, whether or not associated with jet streams, will be found to produce bumpiness with the severity being possibly related also to the wind speed in the faster current. Other factors, not herein discussed, which can produce bumpiness in clear air, are associated with thermal currents over hot deserts in summer and with the eddies that occur near mountains.

However, in the instance for May 23, 1951 (see Figs. 10 and 11), an unusual set of factors seems to be present, illustrating the desirability of knowing the direction of flight when analyzing reports of clear air turbulence. As shown by the arrow, we note that the aircraft was flying in a zone of considerable horizontal shear, whereas the vertical shear seems to have been negligible (Fig. 12).

An Example of Severe Jolts Encountered in Clear Air Above 35,000 Ft.

On October 6, 1951, at approximately 4 p.m. EST, a jet-fighter aircraft flying in the vicinity of Frederick, Maryland, reported "choppy hard jolts affecting air speed" at both 36,000 and 39,000 ft. The aircraft was either climbing or descending, and the pilot classed the jolts as "severe." Frederick, Maryland, is about halfway between Harrisburg, Pennsylvania, and Washington, D.C., both of which reported upper wind data taken as of 4 p.m., so that in this instance a rather detailed examination of the wind structure is possible, but no information is available regarding the heading of the aircraft.

On the analyzed 300- and 200-mb. charts for October 6, a strong westerly current is indicated north of Harrisburg from northern Ohio through northern Pennsylvania and southern New York State. However, in the vicinity of Harrisburg at 4 p.m., we find, as shown in Fig. 11, a strong wind from the west-northwest setting in above 30,000 ft. This appears to be a current that is branching off from the main east-west current lying to the north. Over Washington, D.C., this current appears, as shown in Fig. 12, cutting in at 35,000 ft. into an otherwise weaker wind current from the southwest. Whether our jet pilot struck this new

wind environment head on, thus encountering a sudden and rapid change in air speed, is not known. Nevertheless, it would appear that in this instance a traverse through a marked shear zone would be made in any climb or descent in this area.

Conclusions

Turbulence that is encountered at high levels in clear air has been found to be associated with marked wind shear in agreement with Harrison, Bannon, Hislop, and others. The mechanism that results in the bumpiness felt by the aircraft is still in doubt, and it is believed that further detailed measurements of the phenomenon accompanied by data on the heading and rate of climb of the aircraft will aid in the quantitative determination of the effect proposed by Lange. Also, it is still believed premature to discount Lange's proposal on the premise that the necessary wind shear would be unrealistically and abnormally high, since only a new and detailed survey of the jet stream using improved wind-measuring devices can properly settle that question.

Meanwhile, the questionnaire is supplying a wealth of much needed data on the nature and severity of bumpiness or jolts as encountered in clear air, and analysis of the reports is continuing.

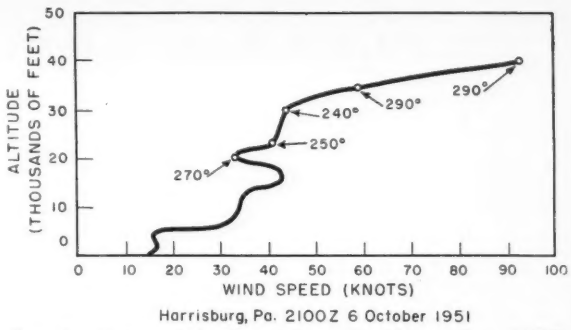

Fig. 13. Upper wind observation, Harrisburg, Pa., 2100Z, October 6, 1951.

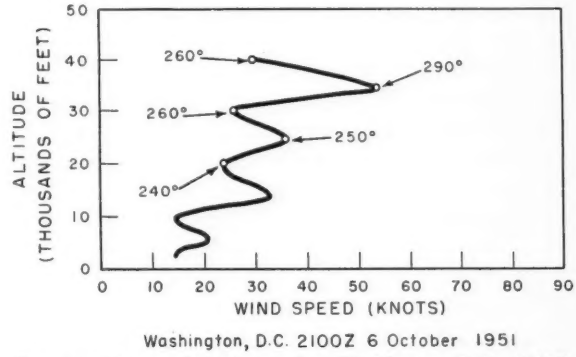

Fig. 14. Upper wind observation, Washington, D.C., 2100Z, October 6, 1951.

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The Airplane Growth Factor and How to Control It

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Introduction

THIS PAPER IS CONCERNED with the weight, size, and cost of current and future military aircraft, particularly those used by the Navy from carriers. These aircraft like other weapons have a consistent history of increasing size and complexity. This is one important factor contributing to the national effort required to conduct warfare—with each new war the population becomes more and more involved to a greater and greater degree. One of the important questions confronting civilian and military leaders alike is: Does a limit exist beyond which this nation cannot support military aviation in sufficient numbers to ensure combat effectiveness, and, if so, what is this limit for the different types required? I believe such a limit does exist—perhaps not in the accepted sense of a hard, fast line beyond which complete catastrophe will result, but a limit reflected in our overall ability to wage a successful armed defense of American principles without the ultimate internal sacrifice of the American way of life. It is apparent to nearly everyone that we are approaching such a limit and, further, that this trend must be controlled or reversed.

Airplane growth is a many-headed monster that derives its vitality from so many sources that one is almost bewildered as to how to attack the problem. The growth factor, or ratio between the gross weight and the military load, is an essential part of any such attack. Analyses, both generalized and particular, have demonstrated that this growth factor is a function of the environment within which the aircraft must operate, the state of the art of airplane and engine design, and the desired performance. The military load, on the other hand, is much more arbitrary and subject to the desires of individual planners or of equipment committees who may tend to specify the ultimate in equipment performance without a full realization of the resulting effects of their desires upon the overall aircraft and its effectiveness.

After all, in the Navy, we must first have aircraft that will operate from our carriers, but we also must be certain that they will be effective in combat. This combat effectiveness requires that the performance be equal to or superior to the aircraft of the enemy and that military load be such that a mission has a good probability of success. That is, adequate armament, including the sighting system, adequate directive and navigating systems, and reasonable protection and comfort to the pilot must be provided. Items of equipment which do not contribute strongly to this combat effectiveness must be cast out, and some others must be studied in the light of the overall effect upon the aircraft size and, consequently, upon the ability of this country to produce them and to support them logistically in sufficient numbers to be effective. After all, in an analysis of the probability of success of any military operation, there are two quantities that must be considered, the individual effectiveness of any single unit and the total number of units employed. With any given level of national expenditure, more aircraft can be provided to the services if they are light and simple than if they are heavy and complicated. Furthermore, the availability for combat will be superior in the case of the aircraft with just sufficient equipment for the job to be done because of simpler maintenance and greater reliability.

Presented at the Design Session, Annual Summer Meeting, I.A.S., Los Angeles, July 16–18, 1952.

* Director, Research Division.

The Growth Factor

The numerical value of the growth factor (G.F.), or ratio between gross weight and military load, determines the cost in weight and in logistics which must be assessed to any added requirement either in military load or in excessive performance. This growth factor is also an index of the technical ability of our designers and of the level of knowledge provided by our research. A study of this factor will indicate areas requiring further development and the order of improvement that may be anticipated from such development.

The growth factor is defined by the following simple algebraic treatment:

W_g = gross weight
W_s = weight of structure
W_p = weight of power plant
W_F = weight of fuel, oil and tanks
W_L = weight of military load

It is evident that

$$W_g = W_L + W_s + W_p + W_F \qquad (1)$$

By definition, G.F. = W_g/W_L. Then,

$$\text{G.F.} = 1 \Big/ \left[1 - \left(\frac{W_s}{W_g} + \frac{W_p}{W_g} + \frac{W_F}{W_g}\right)\right] \qquad (2)$$

The three ratios in the denominator of the right side of Eq. (2) may be expressed as

$W_s/W_g = f_1$ ($M_{max.}$, n, w, state of art)
$W_p/W_g = f_2$ ($M_{max.}$, p, L/D at $M_{max.}$ state of art)
$W_F/W_g = f_3$ (combat radius, $M_{max.}$, c, L/D_{cr}, type of tankage specified, state of art)

where

$M_{max.}$ = Mach Number at maximum desired speed
n = load factor
w = wing loading, lbs. per ft.^{2}
p = specific weight of power plant, W_p/T
T = thrust in pounds
$(L/D)_{M max.}$ = lift drag ratio at $M_{max.}$
c = specific fuel consumption of engine, $(W_F/H_R)/T$
L/D_{cr} = L/D at cruising speed

Methods of Study

The above ratios may be studied in three ways, from the statistical data for previous aircraft, from a generalized analysis, or from specific design studies. The statistical approach is of some value in that it indicates the road that has been traversed, but it fails to indicate the future except by extrapolation of a trend. This is an unsatisfactory process since it fails to show what can and should be done toward improvement and what the resulting effects are likely to be. If we should plot the statistics for a few of the above ratios including the military load being carried in a Naval fighter, for instance, we might conclude quickly that our aircraft are becoming asymptotic to an infinite weight within a short time. This statistical analysis has been employed by the writer in bringing out these points and inducing an understanding of the problems confronting the Navy. Specific design studies of aircraft with greater performance or carrying more load fail to emphasize the problem, because there is always a feeling among lay personnel that some other design might solve the problem more satisfactorily. However, the statistics show the results obtained by the industry as a whole, and anyone can grasp the effects of a moderate extrapolation. As an illustration, Fig. 1 shows a curve of the military load specified in Naval General Purpose Fighters over a period of years. At present this curve is rising nearly vertically with time, and an extrapolation indicates this total will double in 10 years. Taking the growth factor of a current aircraft at, say, about 12 and a military load of 2,500 lbs., the resulting aircraft will weigh 30,000 lbs. If the load doubles, the weight becomes 60,000 lbs., with no increase in performance. Then with similar extrapolation for the structural weight (see Fig. 2), power plant, and fuel ratios to obtain the performance required in 10 years, where we are headed becomes apparent to anyone. The growth factor may rise to 20 or above and a 120,000-lb. fighter result.

FIGURE 1
MILITARY LOAD VS. YEAR FOR FIGHTER AIRCRAFT

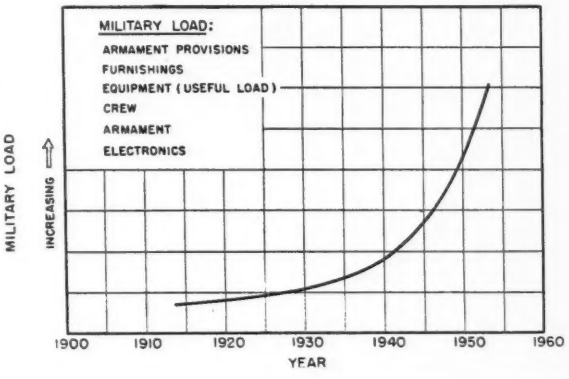
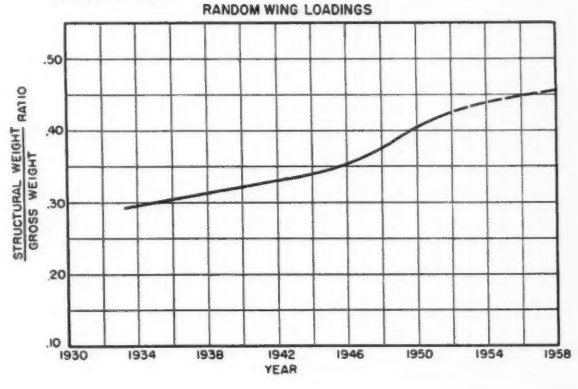


FIGURE 2
STRUCTURAL WEIGHT / GROSS WEIGHT RATIO VS. YEARS FOR FIGHTER AIRCRAFT
RANDOM WING LOADINGS



A convenient and effective means of presenting this statistical approach is the device, a photograph of which is shown in Fig. 3. The four sectors represent the percentage required by the structure, the power plant, the fuel and tanks, and the military load. They are each movable on the original and are calibrated in speed (knots at any chosen altitude) and combat radius, as applicable. The movement of these sectors to increase the performance decreases the sector allowable for military load to absurdly low values. A simple demonstration with this device shows how the size and weight of an aircraft increases and approaches infinity as the size of the military load sector approaches zero. These graphs and the sector chart show what has been done and, by a moderate extrapolation, demonstrate where we may be going unless steps are taken to control the trends observed.

The generalized analytical approach will be employed in this paper, because it tends to highlight need for development and research in many areas and to provide means for assessment of the gains that may be anticipated therefrom. Furthermore, the cost due to unrealistic requirements can be readily demonstrated.

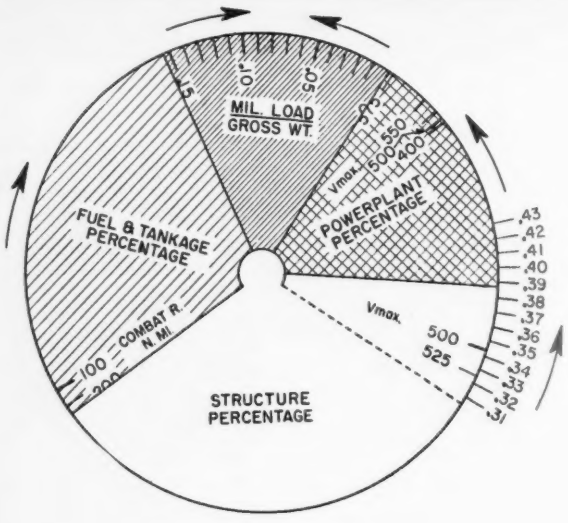
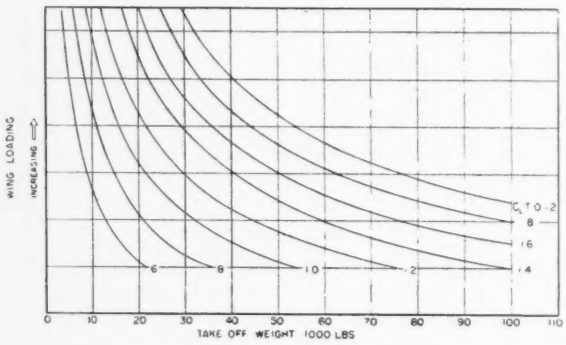


FIGURE 3
SECTOR CHART

FIGURE 4
CATAPULT CAPABILITY
TYPICAL



The Environment

Since this paper will be confined to a discussion of Naval aircraft, primarily, it is necessary to begin any analysis with the characteristics of the environment within which the aircraft must operate—namely, the carrier and its catapult. This is not necessarily because the use of a catapult puts any special limits upon airplane design; on the contrary, the mechanized airfield provided by the aircraft carrier brings many blessings. But the catapult has certain unique characteristics that must be considered in the design of an airplane. These characteristics can react favorably or unfavorably upon the aircraft, depending upon the way in which our problems are solved. The ability of these machines to accelerate aircraft to flying speed is given by a relation similar to the following:

$$W_g(V_{T.O.} - VW)^2 = K \qquad (3)$$

where

W_g = gross weight at take-off
$V_{T.O.}$ = take-off speed or minimum speed in knots at which level flight can be maintained
V_w = wind speed in knots over the deck due to natural causes and the speed of the carrier; the usual value is 25 knots

Eq. (3) may be transformed to read

$$W_g\left(0.592\sqrt{\frac{w_{T.O.}}{\rho/2C_{L_{T.O.}}}} - 25\right)^3 = K \qquad (4)$$

where $C_{L_{T.O.}}$ = lift coefficient at take-off speed and w = wing loading at take-off.

Fig. 4 illustrates a series of solutions of Eq. (4) with a few values of $C_{L_{T.O.}}$ which might be obtained. The value of K was chosen as indicative of a practical number, although no numerical values are shown for security reasons. Those who have need and clearance to use this information can obtain the numerical values upon request.

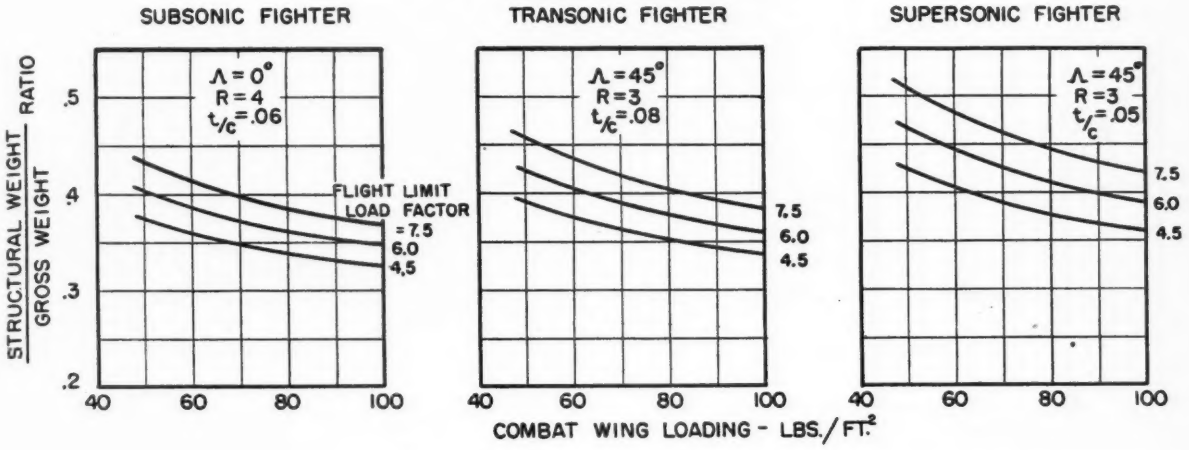
A study of Fig. 4 shows that the wing loading must decrease as the gross weight increases. This is just contrary to the trends that might be obtained from Froude's law or from an analysis of aircraft already constructed. The tendency has been to increase the wing loading as aircraft have grown larger. This fact, among others, may account for our escaping the effects of the square cube law, to date. However, if we must decrease the wing loading as the take-off weight goes up, we will run head on into that law, and linear dimensions will increase approximately as the gross weight of the 5/6 power; consequently, the structural weight will increase (according to the square cube law) as the weight to the 5/4 power. This analysis is rough, indeed, but does serve to demonstrate the necessity for reducing the weight of carrier aircraft. Since the wing loading that can be used is a quantity tied to the carrier and its catapult by Eq. (4), the following discussion will retain that value as a fundamental parameter.

Structural Weight Ratio

The three sections of Fig. 5 give the ratio W_s/W_c versus wind loading for a series of Naval aircraft with the total design load factors indicated on the curves. Each section applies to the plan form and aspect ratio indicated. The data employed for the calculation of these curves were obtained from reference 1. Similar charts may be obtained for other wing designs by application of the data given in this reference. The dimensions and designs chosen are those that might be applicable to a fighter with a maximum speed consistent with the wing design chosen; for instance, the thin straight wing might be used at high subsonic speeds; the 45° sweptback design at transonic values; and the Delta or very thin swept design at supersonic speeds. The fuselage weights were estimated after making a few rough sketches of various designs. Naturally, data such as this can be considered indicative of trends only and cannot be applied to determine

FIGURE 5

STRUCTURAL WEIGHT / GROSS WEIGHT RATIO VS. COMBAT WING LOADING FOR SEVERAL FLIGHT LIMIT LOAD FACTORS



the definite characteristics of any specific design. However, the trends illustrated are extremely pertinent to this overall study. Another point not shown in this analysis is the effect of size (rather than weight) as that factor determines the number of aircraft which can be accommodated upon a carrier. Also, if the airplane becomes small enough, wing folding mechanisms and possibly hydraulic controls can be eliminated. This will result in a further saving in the structural weight percentage, a further reduction in the Growth Factor, etc.

It is probable that further improvements in the structural percentage can be made by the following developments: (1) improved materials, (2) improved manufacturing methods giving higher allowable stresses per unit of weight, (3) better understanding of applied loads, (4) better stress analysis methods taking into account and using all redundancies, and (5) designing to slightly negative margins of safety and proof testing—that is, the so-called "stretching process."

Some of the above suggestions will require additional research; some are a question of engineering policy, but all must be explored and the maximum possible gain obtained. Seemingly, extremely small changes may react upon the whole design in a far from insignificant manner.

Power-Plant Weight Ratio

In general, the size of the power plant to be installed in any fighter aircraft will be determined by the desired high speed, all other items being constant. Then, since the thrust and drag are equal in level flight

$$T = W_c/(L/D)_{Mmax.} \quad (5)$$

$$W_p/W_c = p/(L/D)_{Mmax.} \quad (6)$$

FIGURE 6

WETTED AREA DRAG COEFFICIENT VS. YEARS FIGHTER AIRCRAFT

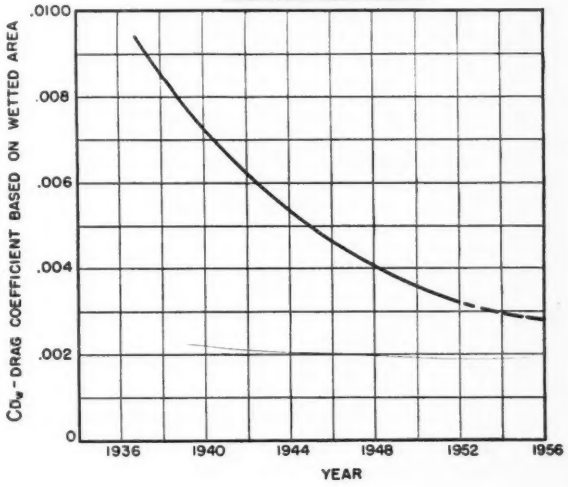


FIGURE 7

TOTAL WETTED AREA / WING AREA RATIO VS. COMBAT WING LOADING FOR TYPICAL FIGHTERS

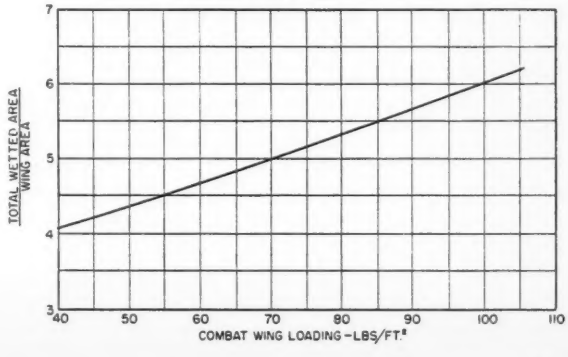
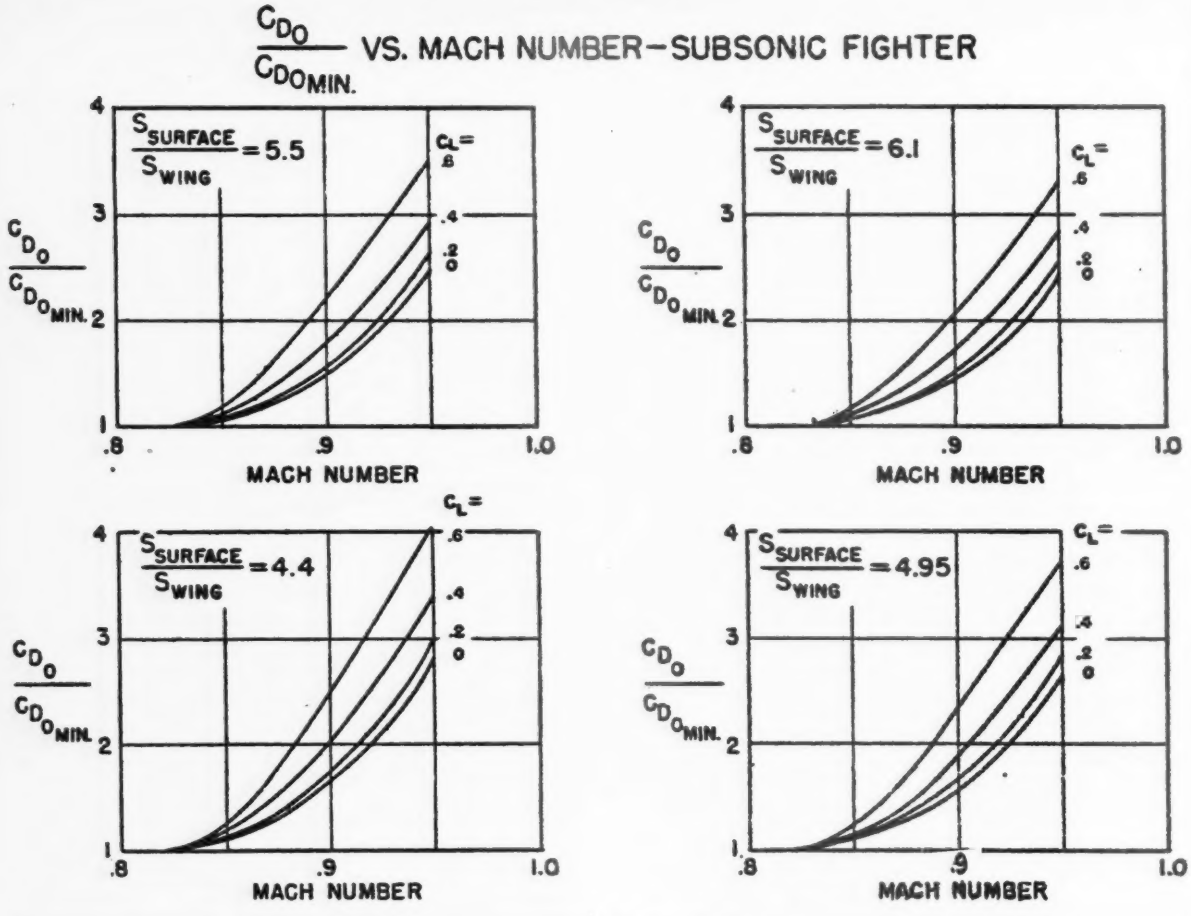


FIGURE 8a



where

W_p = weight of engine plus installation
W_c = combat weight
p = specific weight of engine and installation—lbs. per lb. of thrust
$(L/D)_{M_{max.}}$ = lift drag ratio at $M_{max.}$
= C_L/C_D at $M_{max.}$

The profile drag coefficient, C_{D_o}, without compressibility may be considered to be a function of the total wetted or surface area of an airplane. Fig. 6 shows the trend of the value of the wetted or surface area drag coefficient over the years as obtained from flight tests of numerous aircraft. It is evident that the present values are practically asymptotic to a value of 0.0027 or 0.0028. We will consider that this value (without effects of compressibility) is constant at the value 0.0027. Fig. 7 gives the ratio between the total wetted area and the wing area for the aircraft studied in the previous analysis for the structural percentage. This graph provides data to transform the drag coefficient estimated above from Fig. 6 to a coefficient based upon wing area—that is, to obtain C_{D_o}, without compressibility. Figs. 8a, 8b, and 8c show a series of ratios between this low-speed coefficient and the true C_{D_o} with compressibility as a function of M, C_L, and the ratio of wetted area to wing area and wing configuration. These data are the best available at the present time, but no brief is held for their accuracy except that reasonable checks are obtained with flight and wind-tunnel tests. Now,

$$C_L = K[(w/\delta)/M^2] \tag{7}$$

where

δ = relative pressure at any altitude
M = Mach Number
C_L = lift coefficient = $w/(\rho/2V^2)$

and

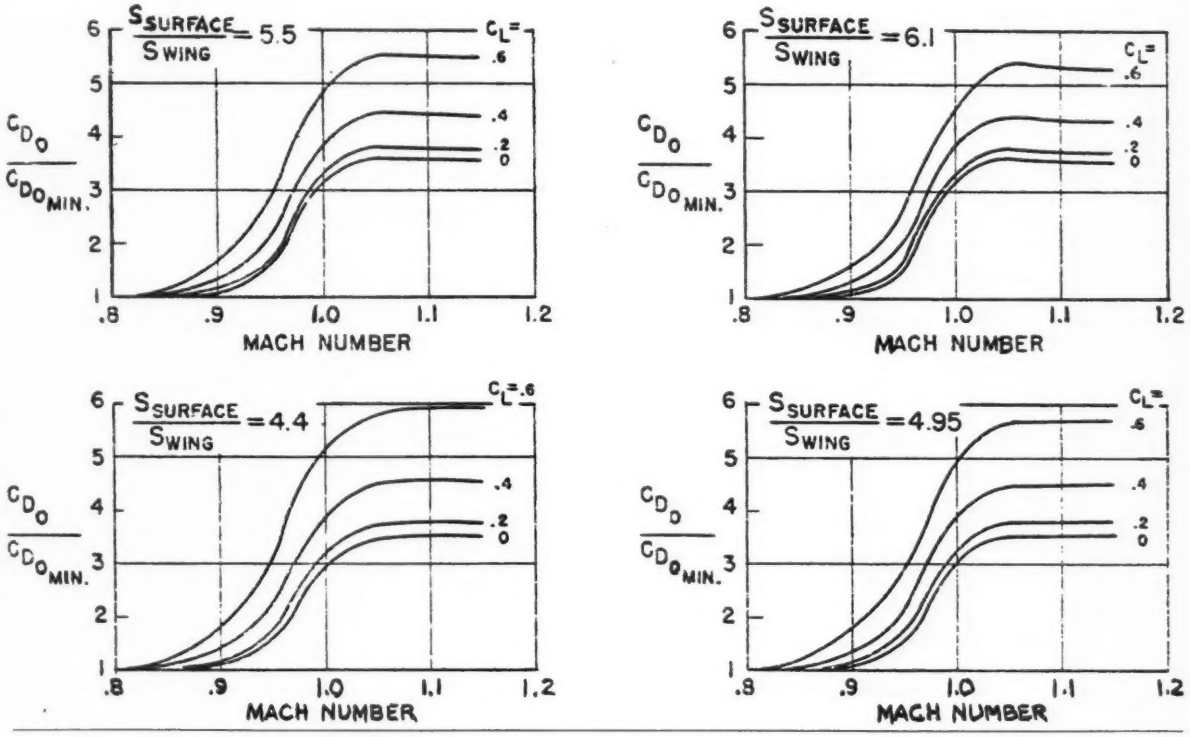
$$\frac{\text{drag}}{\text{weight}} = \frac{K_2 C_{D_o} M^2}{w/\delta} + K_3 \frac{w/\delta}{R_e M^2} \tag{8}$$

R_e = aspect ratio, equivalent. This expression is derived from those given in reference 1.

Using Eqs. (7) and (8) with Figs. 8, the lift coefficient is eliminated, and curves for the three designs are ob-

FIGURE 8b

$\frac{C_{D_O}}{C_{D_{O_{MIN}}}}$ VS. MACH NUMBER – TRANSONIC FIGHTER



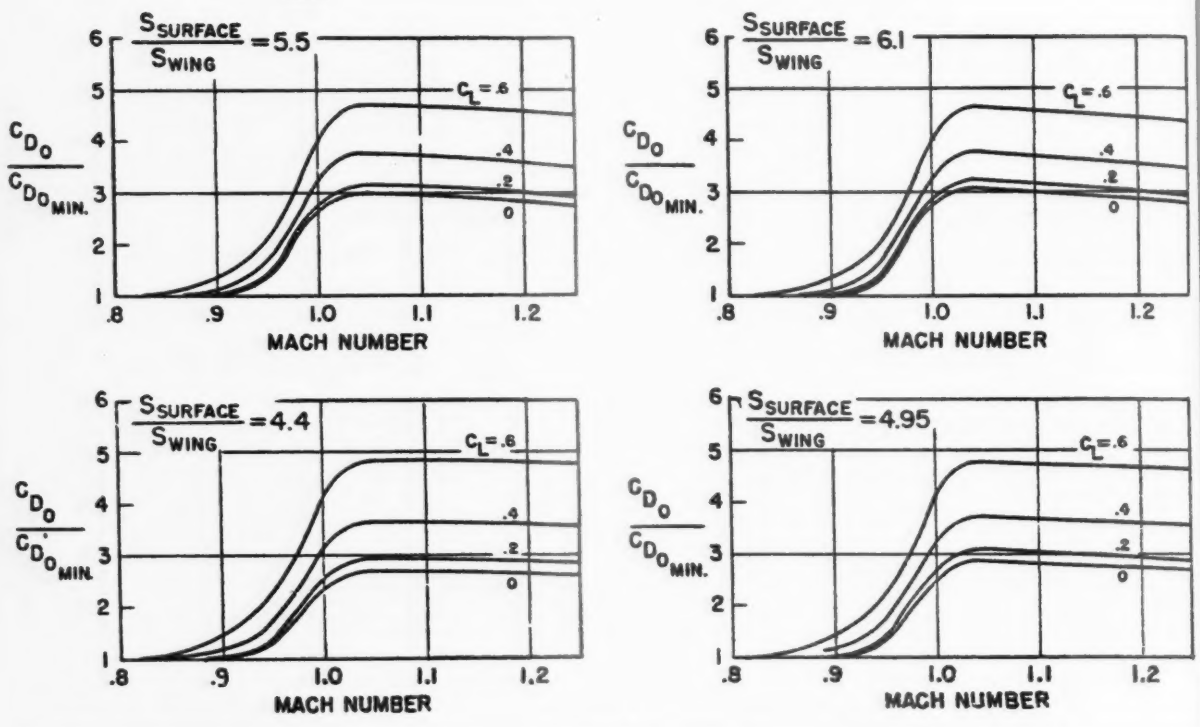
tained which give L/D versus M for a series of equivalent wing loadings. Figs. 9a, 9b, and 9c give the result of this calculation.

Figs. 9 demonstrate that the L/D at $M_{max.}$ increases rapidly with corrected wing loading (w/δ) at the higher Mach Numbers; at 35,000 ft., for instance, where δ equals approximately one-quarter a loading, w, equal to 60 lbs. per sq.ft., is equivalent to altitude value of 240 lbs. For a supersonic airplane designed for M equal to 1.2, the L/D will equal 3.3 (S_s/S_w = 4.4), while, for the same airplane with a loading of 120 lbs. per ft. (sea level), w/δ will equal 480, and the L/D will rise to 5.2. Further, if w equals 150, then the L/D will become 5.85. Therefore, everything else remaining the same, the power-plant percentage will be reduced 36.7 and 43.7 per cent for the above changes in loading, respectively. That is, to do the same overall job, the power-plant *size* can be reduced, not by the above percentages but by much larger ratios, since there will be a cumulative effect with the catapult and structure which will reduce the growth factor and, thereby, lower the combat weight. The above percentages would apply only to the size of the engine if the combat weight were constant. Again, we find the spiral that can affect our overall designs either unfavorably or favorably if this fact is properly understood and applied.

Naturally, if the smaller engine that might result from the above reversal of the logarithmic spiral of expansion has a higher specific weight than the larger one, some of the advantages shown above will be lost. Reference 2 provides a thorough study pertinent to this point. Data from this report were used in plotting Fig. 10, which shows engine specific weight plotted against static sea level thrust, no augmentation. Numbered points apply to specific axial-flow turbojet engines now installed in Naval aircraft. Therefore, the abscissas and ordinates are unidentified for security reasons. It will be noted that all engines except No. 4 show exactly the same general trend as the curve obtained from reference 2. Furthermore, the manufacturers of certain of these engines are already quoting increases in thrust which will be obtained after further development. The primed numbers apply to these advanced ratings. These points lie practically upon the curve as calculated from the British report. This would lead one to believe that the other American engines could be improved similarly by intensive development effort to agree with the calculated data or at least to follow the general trend with size. From

FIGURE 8c

$\frac{C_{D_O}}{C_{D_{O_{MIN.}}}}$ VS. MACH NUMBER—SUPERSONIC FIGHTER



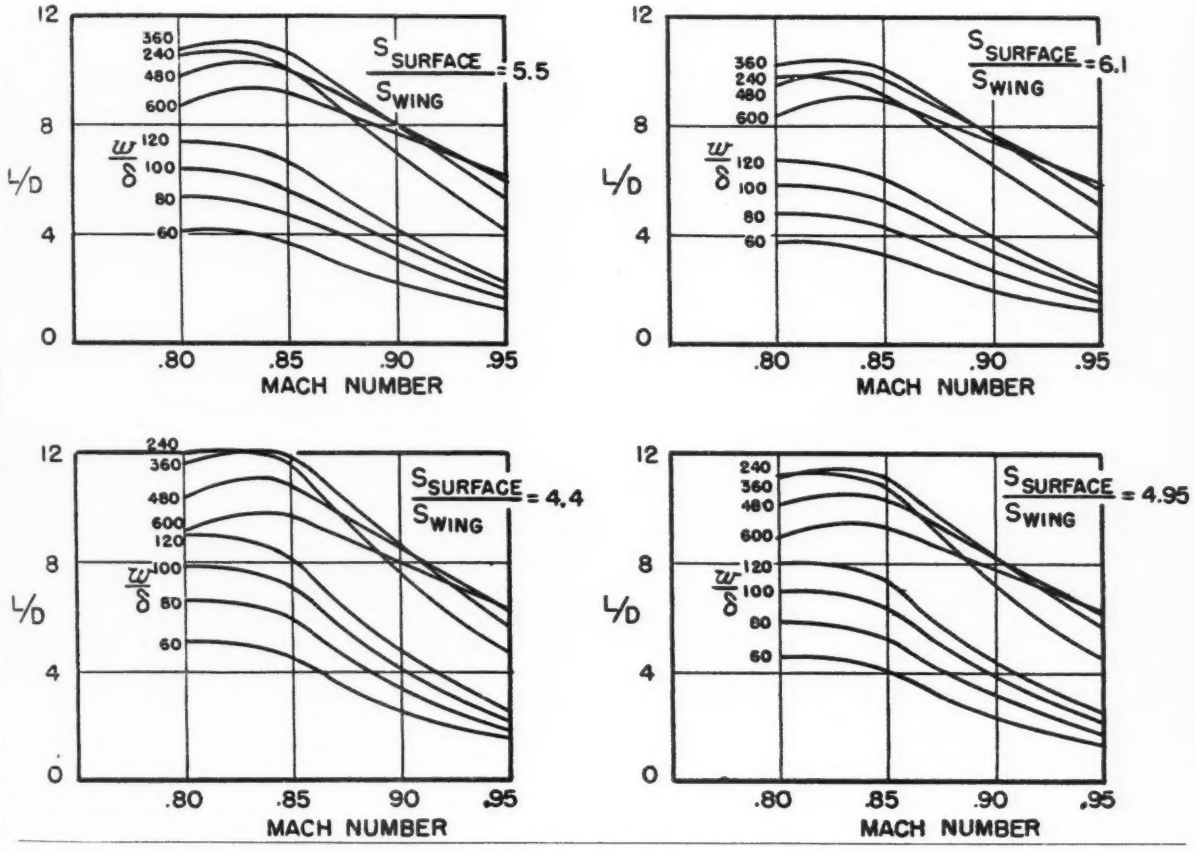
these data, then, we have another factor entering into our spiral—favorable if weight is reduced and unfavorable if it is increased. It must be realized, of course, that afterburning, with the consequent large increase in thrust, will materially affect any absolute values obtained for bare engines, but the trends should be unaffected. Also, the lapse rates with altitude and speed may be different for the series of jets shown, but there is no reason why, in further development, any deficiencies in these respects, if existent, cannot be corrected in the smaller engines. It is possible also that further reductions can be made in the engine specific weight by the following: (a) improved materials, (b) elimination of excessive gearbox weight that now results from multiple large power take-offs, (c) improved aerodynamics, and (d) continued development of existing engines to operate on a more favorable point on the "learning curve."

It is also possible that further reductions in W_p/W_e can be effected by using two small jets in place of one larger one. Extreme care will be required in the design, however, if the gain due to the lower weight of the two is not to be lost in greater installation weight and drag. Studies made in the preparation of this paper of single- and twin-engined turbojet aircraft have shown that any jet engine *can* be installed for about 5 lbs. per 100 lbs. of thrust. The slope of the line of Fig. 10 is greater than 0.05, so it becomes evident that two smaller engines after installation—again let us emphasize carefully done—can provide a lighter power-plant weight than one larger unit. This is true even though some errors in weight accounting were made in the weight reports investigated to obtain the above value of 0.05. That is, different contractors may have listed some weights, rightly chargeable to the power-plant installation, with the fuselage or wing, so that the weight statements did not reflect the true picture. However, the reduction in specific weight with size is more than enough to compensate for such discrepancies.

Fuel and Tankage Weight Ratio

The analysis of the fuel and tankage ratio is complicated by the use of combat radius instead of range. In general, quite a large amount of fuel must be provided for warmup, take-off, climb, combat, and rendezvous before the aircraft starts to go any place. Since nearly all these operations occur at either full-military or full-combat power and are a function of time not of distance, it appears desirable to group the requirements for fuel to cover the warmup, take-off, and climb together; then consider another quantity

FIGURE 9a
L/D VS. MACH NUMBER - SUBSONIC FIGHTER



to cover combat operations and a final allowance for the cruise and rendezvous. This may be somewhat too simplified, but any further breakdown becomes too complicated for ease of handling. Let

$$(W_F/W)_{\text{T.O.}} = K_1 c_{\text{T.O.}} t_1/(L/D)_{\text{T.O.}} \tag{9}$$

$$(W_F/W)_{\text{COMBAT}} = K_5 c_c t_2/(L/D)_c \tag{10}$$

$$(W_F/W)_{\text{CRUISE}} = K_6 c_{CR} \text{C.R.}/M_{CR}(L/D)_{CR} \tag{11}$$

where

$c_{\text{T.O.}}$	= specific fuel consumption at take-off
c_c	= specific fuel consumption at combat
c_{CR}	= specific fuel consumption at cruise
t_1	= time of take-off and climb
t_2	= time of combat
$(L/D)_{\text{T.O.}}$	= lift drag ratio at climb and take-off
$(L/D)_c$	= lift drag ratio at combat, see Fig. 8
$(L/D)_{CR}$	= lift drag ratio at cruise
C.R.	= combat radius, nautical miles

The reciprocal of the denominator of Eq. (11) is obtained if Eq. (8) is divided by M, thus:

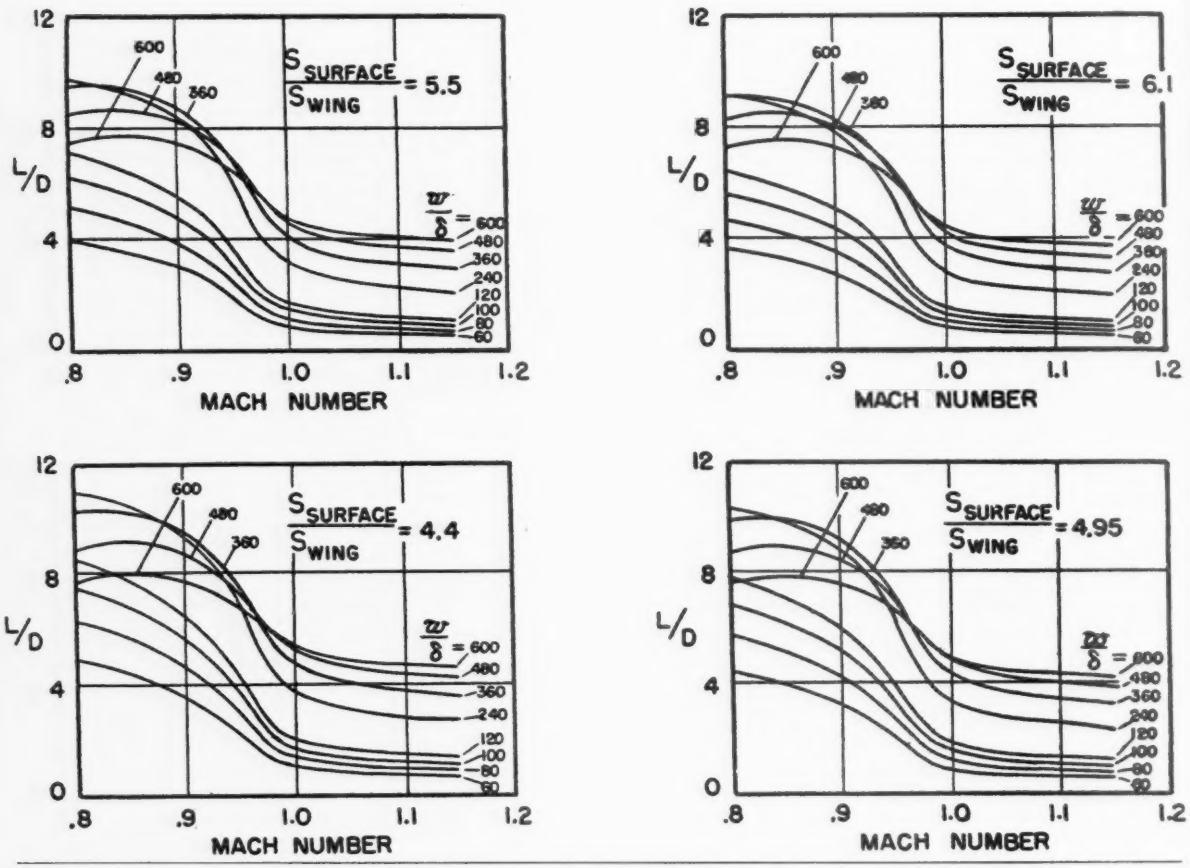
$$\frac{1}{M_{CR}(L/D)_{CR}} = \frac{K_2 C_{D_0} M}{w/\delta} + K_3 \frac{w/\delta}{R_e M^3} \tag{12}$$

Figs. 11a, 11b, and 11c are derived from Figs. 8a, 8b, and 8c for the three aircraft types according to Eq. (12). Then, with the value of c_{CR} known, the cruising fuel to cruising weight ratio can be determined at any combat radius.

It is again evident that high corrected wing loading is favorable in reducing the ratio $1/[(L/D)M]$. This is true for each of the three designs studied at all ratios of surface to wing area. Therefore, from Eq. (11), the fuel required to cruise will decrease as the corrected wing loading increases, everything else being equal. Also, since the L/D at $M_{max.}$ similarly increases with w/δ, the fuel requirements for combat also will decrease according to Eq. (10). That is, it appears that at any desired cruising or high speed the fuel consumption will be reduced by an increase in w/δ. The engine specific fuel consumption is dependent upon the engine design and the speed, so that this factor does not enter except to fix the absolute value of the total ratio W_F/W_c.

FIGURE 9b

L/D VS. MACH NUMBER – TRANSONIC FIGHTER



Returning to reference 2, it appears that as the engine size is reduced the turbojet S.F.C. will be increased, both at cruising and high speeds. This fact is due to the lower Reynolds Numbers of the compressor and turbine blading. Fig. 12 has been calculated from this reference for the static sea level case, and again points are shown, for a group of specific engines, numbered the same as for Fig. 10. Points 4′ and 6′ apply to the advance ratings of engines 4 and 6. It is notable that these two points lie on a line substantially parallel to the British curve, although about 6 per cent higher. This difference may reflect the margin required by the engine manufacture for guarantee purposes. The important point, however, is that the trend of S.F.C. with size as calculated from reference 2 seems to be correct. Therefore, the use of smaller engines will increase the fuel-tankage ratio required for any design problem at both high and cruising speeds. Whether this effect will be great enough to outweigh the favorable reduction in engine weight and decrease in size will depend upon the combat radius and the total time at full power. If, however, two smaller engines are used in place of one larger unit, the ability to loiter at low altitude on one engine will, in all probability, more than compensate for the higher S.F.C. for the smaller units.

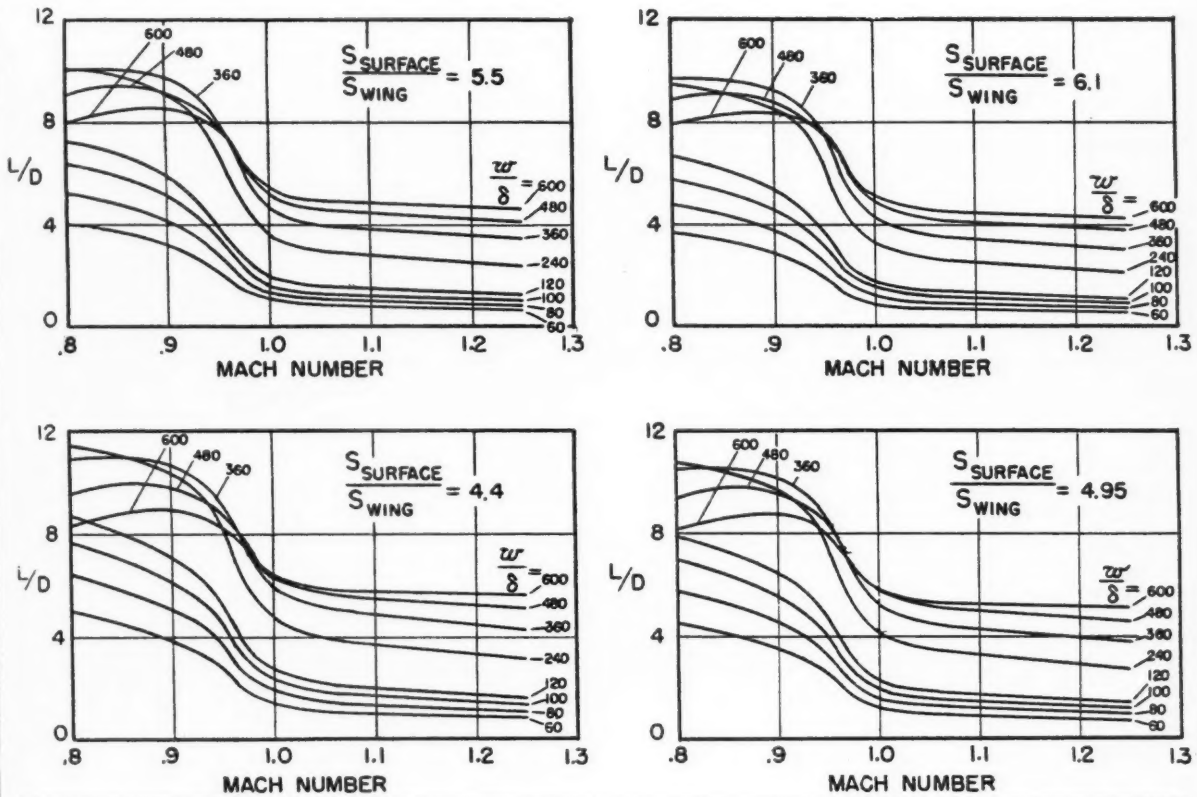
Improvements in the fuel-tankage ratio may be expected from the following: (a) improved engine aerodynamics, (b) improved combustion, (c) elimination of self sealing tanks, and (d) continued development of existing engines.

It is not impossible that values nearer to the British curve can be anticipated. The curves of Figs. 10 and 12 should be considered as goals for the American engine designers.

The Military Load

The preceding sections of this paper have provided data from which the structural, power-plant, and fuel percentages can be estimated. The percentage allowable for the military load, W_L, is the quantity remaining after subtracting the sum of the above percentages from unity. The growth factor is the reciprocal of this remainder. No discussion will be given as to what *can* be done to reduce the value of W_L, since this is not the problem; rather, we must find what *must*

FIGURE 9c
L/D VS. MACH NUMBER - SUPERSONIC FIGHTER



be done and then seek ways and means to do it. As will be seen from the example to follow, the military load is not a completely independent variable to be specified by a committee of experts with no knowledge of aircraft design; rather, it has a fixed and invariable maximum dependent upon the performance required and upon the carrier and its catapult. This maximum can be increased only if the performance is reduced or the characteristics of the catapult improved.

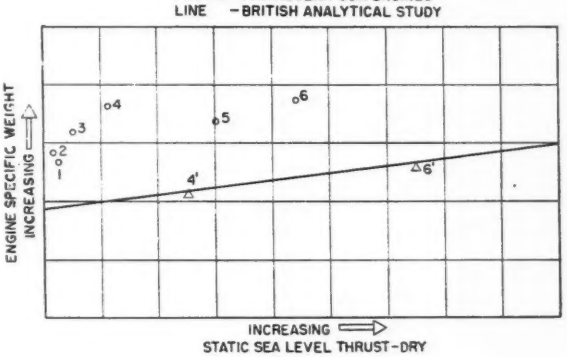
Using the data already presented, an example will be worked out to demonstrate the truth of the above statements. Let

$M_{max.}$ = 1.2 at 35,500 ft.
K = 4×10^{10} in Eq. 4
$C_{L_{T.O.}}$ = 1.10
$W_{T.O.}/W_e$ = 1.20
C.R. = 400 nautical miles

Assumptions: Nonafterburning engines—thrust (35,500 ft., M = 1.2) = $\frac{1}{2}$ thrust at sea level static, p_e from Fig. 10, c from Fig. 12, and $p = p_e + 0.05$ to account for installation.

Afterburning engines—thrust (35,500 ft., M = 1.2) = thrust at sea level static, p_e from Fig. 10, c from Fig. 12 increased 3 per cent for tailpipe losses, and p =

FIGURE 10
TRENDS IN ENGINE SPECIFIC WEIGHT VERSUS THRUST
POINTS - PARTICULAR USA ENGINES
LINE - BRITISH ANALYTICAL STUDY



1.1 p_e + 0.05, to account for installation plus heavier tailpipe, nozzle, fuel system, etc.

Calculations, not repeated here, give:

W_F/W_C for 400 nautical miles, 0.205; one nonafterburning engine

W_F/W_C for 400 nautical miles, 0.241; one afterburning engine

W_F/W_C for 400 nautical miles, 0.194; two nonafterburning engines of $\frac{1}{2}$ size

TABLE 1

$W_{T.O.}$	$w_{T.O.}$	W_c	w_c	w_c/δ	L/D M=L2	$\frac{W_s}{W_g}$	TH. REQD	TH. S.L.	Pe S.L.	TH. S.L.	Pe S.L.	TH. S.L. EACH ENG.	Pe S.L.
10,000	126	8333	105	435	3.6	.415	2315	4630	.305	2315	.275	2315	.275
20,000	85.8	16667	72.4	315	3.3	.460	5060	10120	.377	5060	.311	5060	.311
30,000	72.5	25000	60.4	263	3.10	.480	8070	16140	.452	8070	.352	8070	.352
40,000	58.2	33333	48.4	211	2.80	.490	11900	23800	.548	11900	.398	11900	.398
								Single Non-A.B.		Single A.B.		Twin Non - A.B.	

	Non A.B. Single				A.B. Single				Non A.B. Twin			
$W_{T.O.}$	$\frac{W_p}{W_c}$	$\frac{W_p+W_s+W_F}{W_c}$	$\frac{W_L}{W_c}$	W_L	$\frac{W_p}{W_c}$	$\frac{Wp+W_s+W_F}{W_c}$	$\frac{W_L}{W_c}$	W_L	$\frac{W_p}{W_c}$	$\frac{Wp+W_s+W_F}{W_c}$	$\frac{W_L}{W_c}$	W_L
10,000	.196	.816	.184	1530	.098	.754	.246	2050	.1805	.7895	.2105	1750
20,000	.258	.923	.077	1205	.1195	.8205	.1795	2800	.219	.873	.127	2120
30,000	.324	1.009	.009	—	.141	.862	.138	3450	.259	.933	.067	1675
40,000	.426	1.121	.121	—	.174	.905	.093	3169	.320	1.004	.004	—

FIGURE 11a

$\frac{1}{(L/D)M}$ VS. MACH NUMBER – SUBSONIC FIGHTER

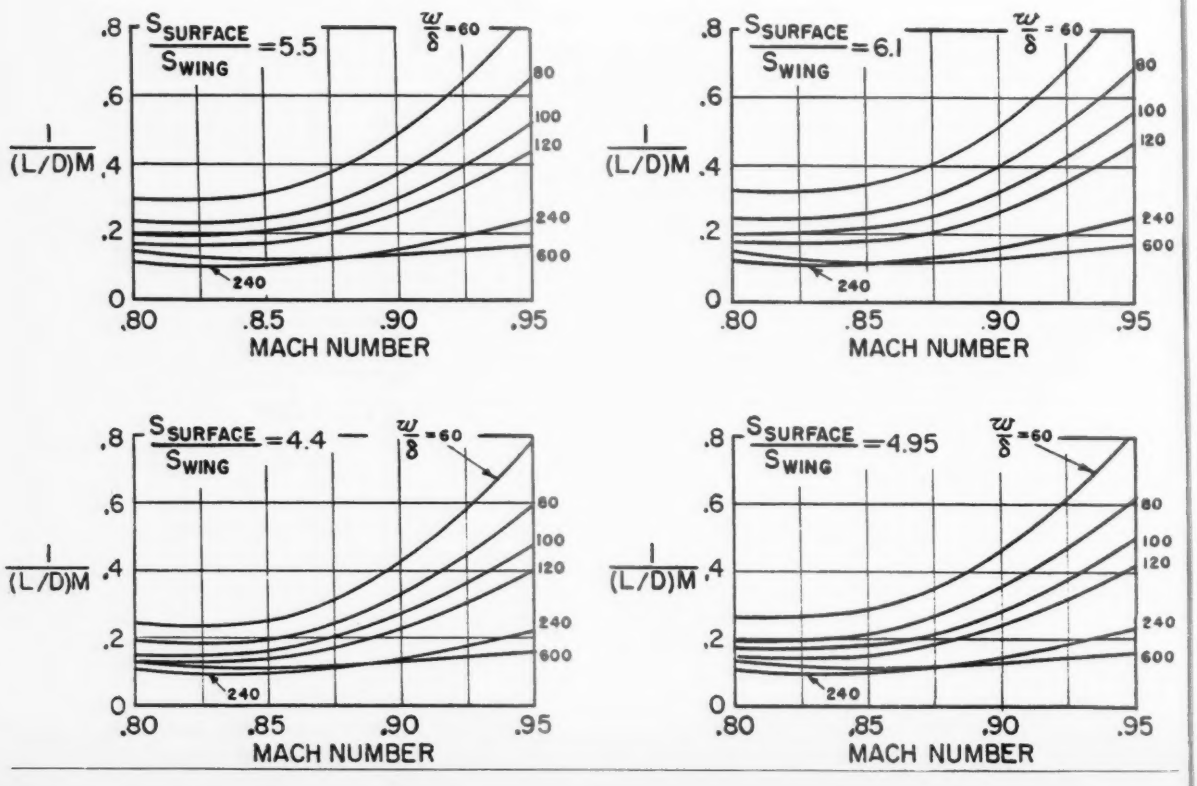
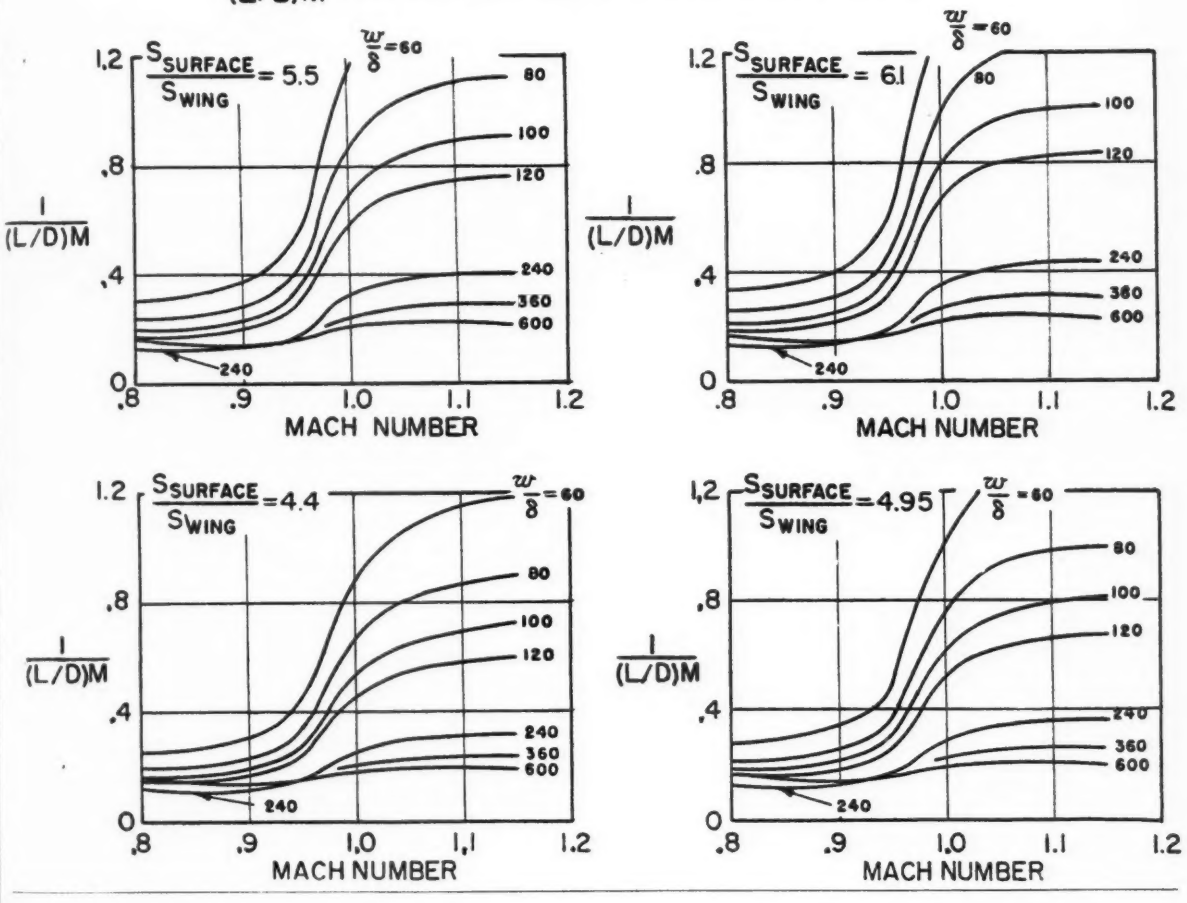


FIGURE 11 b

$\frac{1}{(L/D)M}$ VS. MACH NUMBER–TRANSONIC FIGHTER



Four take-off weights are chosen and Table 1 is filled in using data from Eq. 4, and Figs. 5 and 9c. Each weight corresponds roughly to a value of S_s/S_w given on the latter graph.

The values of W_L from this table are plotted on Fig. 13 with one additional point for the 10,000-lb. airplane. For this value it was assumed that the airplane would be small enough so that the wing folding mechanism and the hydraulic control system could be eliminated. A 3 per cent saving in W_s/W_g was assumed for this improvement.

Since this analysis assumed the calculated specific weight and specific fuel consumption curves of Figs. 10 and 12, the results must be considered greatly optimistic until such time as American engines are available which equal or exceed the performances indicated by those data. A more realistic analysis would increase p_e and c by about 35 and 18 per cent, respectively, to represent the average line through the points of Figs. 10 and 12. This has been done for the analysis from which the dotted lines of Fig. 13 were plotted. These curves may be considered as reflecting the present state of the art determined by current turbojet engines, coupled with the best aerodynamic and structural design practice. The curves originally calculated and represented by the solid lines must be considered goals that we should all strive to attain. Similarly, the curves of Figs. 10 and 12 are goals for the engine industry. The first will be extremely difficult or impossible to attain unless the second is also obtained.

Fig. 14 shows the growth factor plotted against the take-off weight. These values are the reciprocals of the W_L/W_C ratios previously calculated.

Although both Figs. 13 and 14 show that more military load can be carried with afterburning engines and would, therefore, be better for the particular problem considered, a consideration of performance requirements at other altitudes where the afterburners were not assumed to operate might lead to the choice of the simple engines. The rate of climb, ceiling, and speeds at lower altitudes would be far better for both the single and twin nonafterburning installations. Far better overall aircraft would be obtained by reducing

FIGURE 11c

$\frac{1}{(L/D)M}$ VS. MACH NUMBER—SUPERSONIC FIGHTER

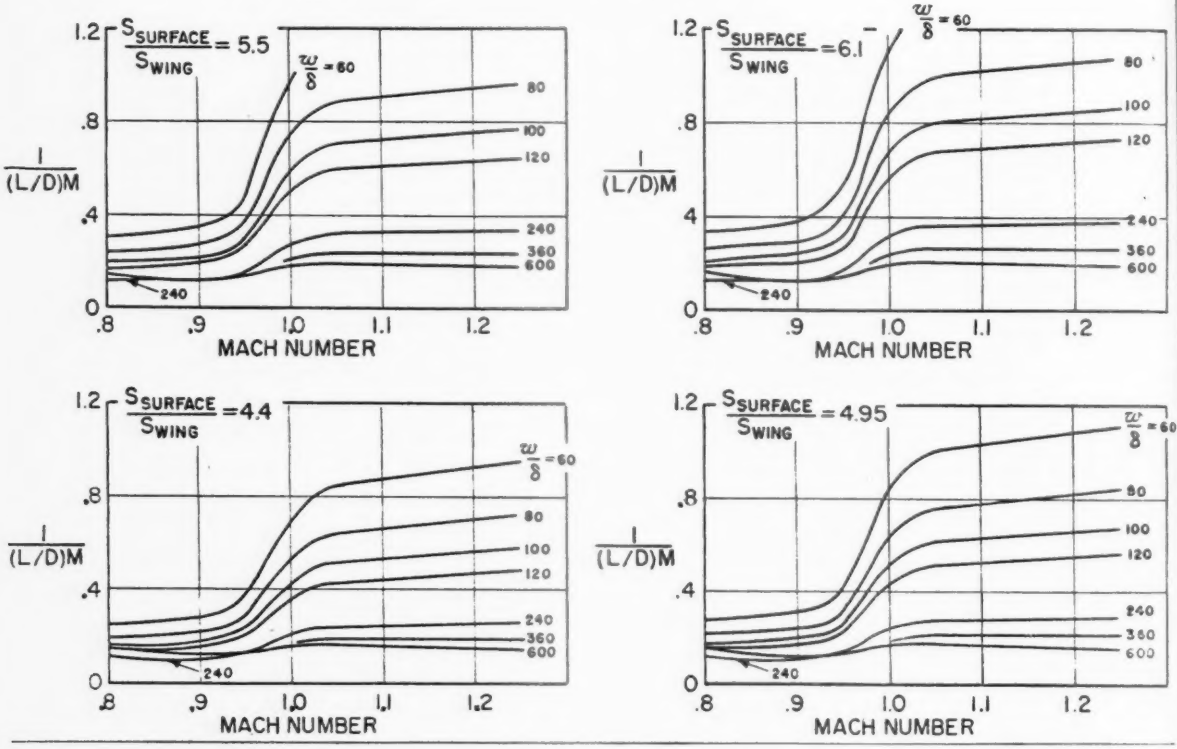


FIGURE 12
TRENDS IN SPECIFIC FUEL CONSUMPTION VS. THRUST

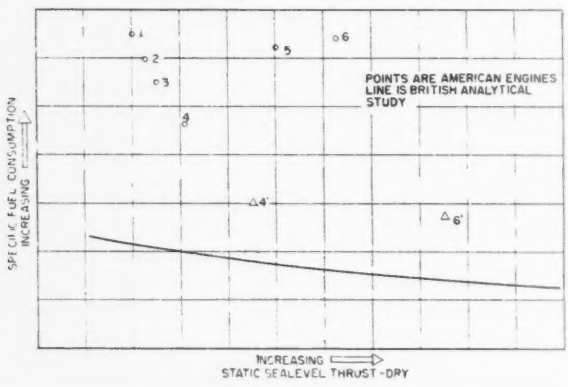
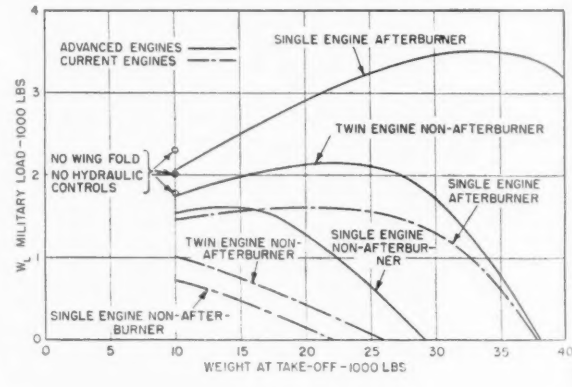

POINTS ARE AMERICAN ENGINES
LINE IS BRITISH ANALYTICAL STUDY
SPECIFIC FUEL CONSUMPTION INCREASING
INCREASING STATIC SEALEVEL THRUST - DRY

FIGURE 13
MILITARY LOAD VS TAKE-OFF WEIGHT



the value of W_L so that afterburners could be eliminated without excessive aircraft size.

It is believed strongly that the military load can be reduced to the values necessary to allow the performance indicated on Fig. 13 with light and simple fighters, where suitable power plants are available. The means to be employed might be:

(1) Design of complete electronic systems rather than a series of units with duplicate power supplies, computers, etc., and the elimination of large, heavy connecting cables.

(2) Realistic operational evaluation of the armament specified, particularly the number of rounds of ammunition.

(3) Elimination of all duplicate hydraulic systems. If such systems are unreliable, improve them. Do not duplicate an error.

(4) Study all requirements for luxury or comfort items, making certain that the combat effectiveness of the airplane-pilot team is improved by their retentions.

(5) Examine every item specified and every detail specification in the light of the cost in overall weight incident to its inclusion. That is, educate the people who insist on including items that cause our military loads to become excessive. Enlightened common sense is a very valuable asset to any program such as this.

(6) Give our air-frame contractors greater responsibility in the control of equipment items and remove them from the Government Furnished Equipment categories.

Conclusion

(I) For aircraft to be launched from a given catapult, the military load is not an arbitrary quantity to be specified at will along with the performance required to ensure combat effectiveness; rather, there is a limiting value of W_L which cannot be exceeded without sacrificing performance. Increasing take-off weight to provide greater military load beyond an optimum point will result in either a loss in load or a decrease in performance. Stated another way, a point is reached, as the take-off weight increases, at which the returns in terms of W_L become zero and then become negative. Even in the region where increasing gross weight permits an increasing load, the gains are slow with respect to the gross weight. For afterburning single engines the best value noted is 750 lbs. per 10,000 lbs. of increased gross weight; for twin nonafterburning engines, it is 340 lbs. per 10,000 lbs.

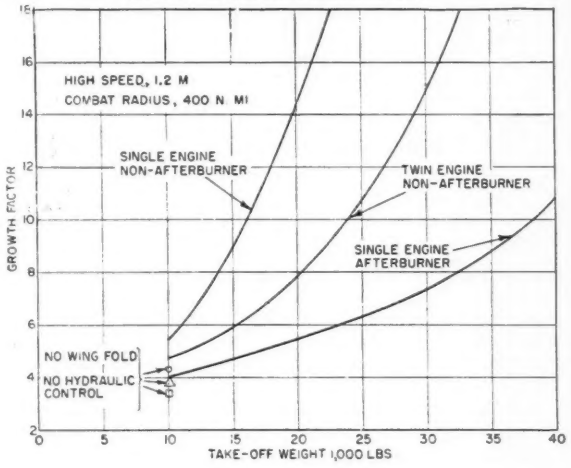
(II) In general the outlook for high-performance aircraft at moderate weight is substantially brighter than even a few months ago. But to achieve these objectives will require more thoughtful effort on the part of *all* those concerned with aircraft—the air frame, the engine, and all other components making up the airplane.

(III) One field in which there is clear evidence of potential improvement is that of the power plant. Our British friends have shown that engine performance can be better than today's American engines. Are we going to let this challenge lie unanswered?

(IV) Again, in the engine field, care must be used in selecting engine size and augmentation.

(a) For larger values of military load in aircraft operating from a given catapult, a small engine augmented by an afterburner is superior to a larger unaugmented engine. The value of military load at which this occurs depends on the state of the art of catapult, air-frame, and engine design; furthermore, the result also depends on the flight problem.

FIGURE 14
GROWTH FACTOR VS. TAKE-OFF WEIGHT



(b) For more moderate values of military load, a twin-engined airplane of 10,000 lbs. is essentially equal to a 20,000-lb. similar design, in terms of military load carried.

(c) The twin-engined designs approximate an average between the single units with and without afterburning. This, of course, is only true if the increase in drag caused by such an installation is zero or small in magnitude. However, considerations of altitude flexibility in performance, with greater ceiling, indicates that strong consideration should be given to such designs, and every effort should be exerted to reduce the military load to such a level that all these gains in performance become attainable.

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[1] Driggs, I. H., *Aircraft Design Analysis Methods as Employed by the Research Division of the Bureau of Aeronautics*, NavAer Report 1139, October, 1949.

[2] Moyes, S. J., and Pennington, W. A., *The Influence of Size on the Performance of Turbo-Jet Engines*, Proceedings, Third Anglo-American Aeronautical Conference, Brighton, England, September, 1951.

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Economic Aspects of the *Supersonic Jet Transport*

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Boeing Airplane Company

SUMMARY

Looking a decade into the future, we will no doubt find the commercial transport passenger crossing the country in approximately 4 hours. Man's ever present quest to conquer time and distance, however, means that he will not be content with spending 4 hours flying coast to coast if there is a way of doing it in 2 hours. The purpose of this paper is to extrapolate beyond the high-subsonic-speed aircraft of the next decade and postulate about the economics of a supersonic commercial transport.

INTRODUCTION

FROM THE PASSENGER'S POINT OF VIEW, an increase in speed is desired, provided standards of economy, comfort, reliability, and safety are not compromised. In previous discussions of commercial jet transports, a good case has been presented for the subsonic turbojet transport.† In this reference it is pointed out that the direct operating costs of a jet transport are comparable to those of a piston-engined transport, provided that the operating range is kept below 2,000 miles. The design goal of the aircraft designer for military aircraft has usually been, in order of preference, more speed, more range, and more pay load. As a result of these general requirements, military aircraft have pushed in speed beyond the sonic barrier with some compromise in range, pay load, and altitude operations. It is of interest, then, at this point, to speculate about the supersonic commercial transport and to investigate the compromises on range and direct operating costs as speed increases. To study this problem, it is now in order to examine the airplane design parameters that affect range, particularly in the supersonic speed region and determine the weight and direct operating costs of typical supersonic jet transports.

DESIGN PARAMETERS

In Fig. 1 is presented a postulated variation in lift to drag ratio with increasing Mach Number. In examining the airplane range equation contained in Fig. 1, it is noted that lift to drag ratio, L/D, is an important variable. The maximum lift to drag ratio at supersonic speed postulated for airplanes in this time period is approximately $^1/_4$ of that available for a subsonic turbojet transport. Unless the remaining variables in the range equation are more favorably inclined as speed increases, the range of a supersonic commercial transport would be seriously reduced.

To examine the second variable in the range equation, propulsive efficiency divided by brake specific fuel consumption, η/c, it is necessary first to compare postulated power-plant characteristics of the rocket, ram-jet, and turbojet. Inasmuch as the supersonic speed region is of primary importance in this discussion, propeller-driven power plants are eliminated as possible competitors. If, in the future, an efficient supersonic propeller can be operated, then further study may be justified for this method of propulsion. An examination of the thrust coefficient capabilities of the major power-plant competitors as plotted against Mach Number in Fig. 2 indicates no apparent superiority of any one power plant for the complete supersonic speed region. The turbojet without afterburner is least attractive from a thrust coefficient standpoint. In Fig. 3 the thrust specific fuel consumption characteris-

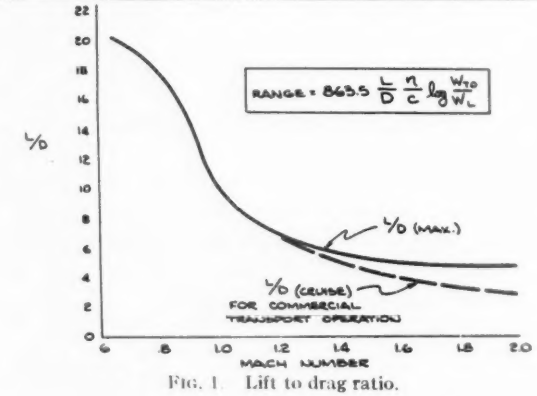

FIG. 1. Lift to drag ratio.

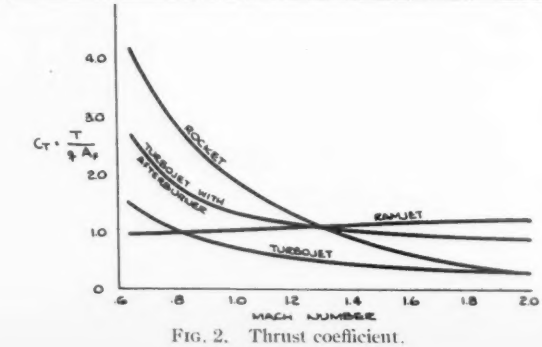

FIG. 2. Thrust coefficient.

* Preliminary Design Department.

† Hage, Robert E., *The Application of Jet Propulsion to Commercial Air Transportation;* Princeton University Press, Princeton, N.J., 1948.

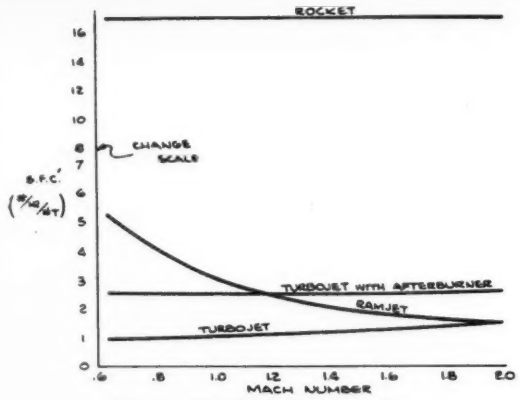

FIG. 3. Specific fuel consumption.

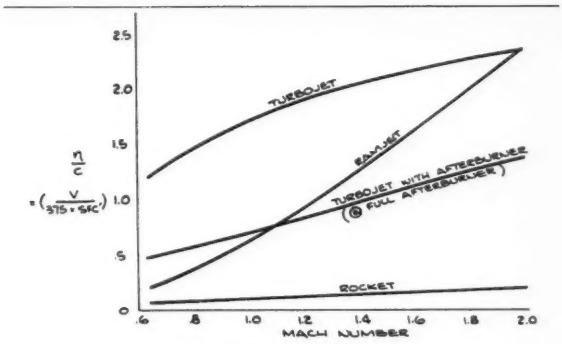

FIG. 4. Propulsion parameter.

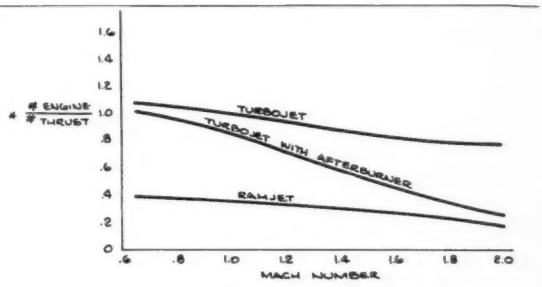

FIG. 5. Specific engine weight.

tics of these power plants are compared. It appears from this comparison that the rocket can now be eliminated as a serious contender because of its tremendous fuel requirements. By dividing the speed by thrust specific fuel consumption, the propulsion parameter, η/c, is obtained and plotted against Mach Number in Fig. 4. In this comparsion, it is noticed again that the rocket cannot compete and that the choice of power plants is now among the turbojet, turbojet with afterburner, and ram-jet. A complete comparison of power plants must also include a comparison of specific engine weight,

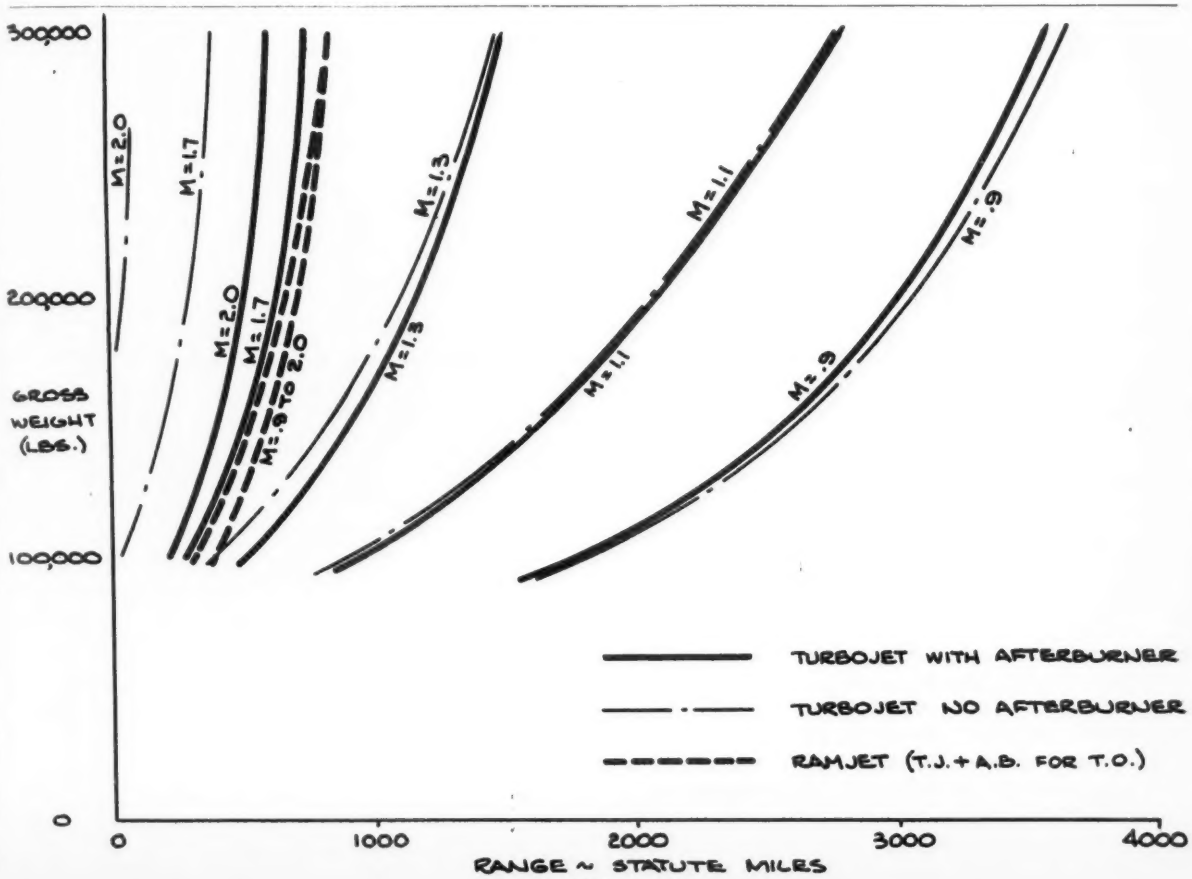

FIG. 6. Airplane weight.

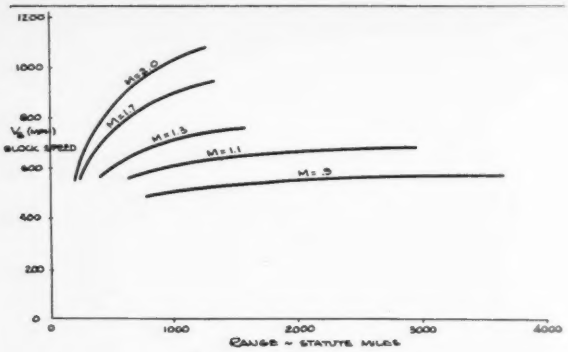

FIG. 7. Block speed.

as illustrated in Fig. 5 for a particular operating altitude.

Starting from these airplane and power-plant data and using as a base point a subsonic turbojet transport as developed in reference 1, new values of weight ratio (take-off weight to landing weight) are calculated for each different type of airplane-engine combination for various values of Mach Number. Airplane gross weights are then computed for different values of range. From several hypothetical designs, the curves of airplane gross weight plotted against range can be drawn as presented in Fig. 6.

Because of particular operation conditions and a lack of basic design data at very high supersonic speeds, certain limitations are imposed within the scope of this study. A maximum operating altitude of 40,000 to 45,000 ft. is chosen to avoid the controversial aspects of passenger safety due to an explosive decompression. A maximum operating Mach Number of 2 is selected to avoid speculating on the adverse structural weight requirements due to the rapid strength to weight deterioration at very high temperatures. Wing loadings are used consistent with conventional take-off and landing procedures for a 6,000-ft. field. It should be noted that the available cruise lift to drag ratio is lower than the maximum lift to drag ratio indicated in Fig. 1 because of these limitations. All ram-jet aircraft considered employ auxiliary power plants for take-off and low-speed operation.

Operating Costs

The direct operating costs of this family of commercial transports are computed according to existing A.T.A. formulas modified for the new power plants where required. Block speeds for various values of cruise Mach Numbers are computed also in a conventional manner and plotted against range in Fig. 7. The direct operating cost data are presented in Fig. 8 for the three most favorable airplane-engine combinations for various values of Mach Number, gross weight, and range. At a Mach Number of 2, the ram-jet is the best power plant selection but, even at best, is considerably more costly than the subsonic transport and is limited to an operating range of less than 1,000 miles.

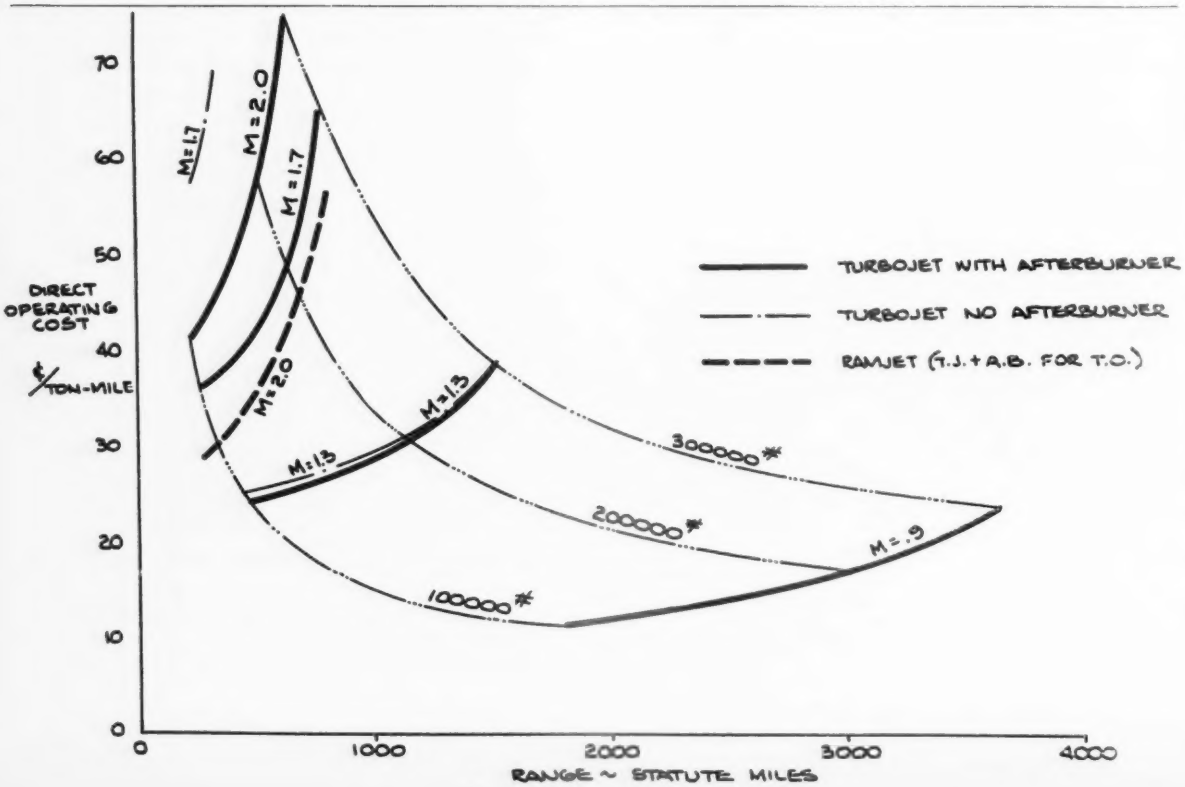

FIG. 8. Direct operating cost.

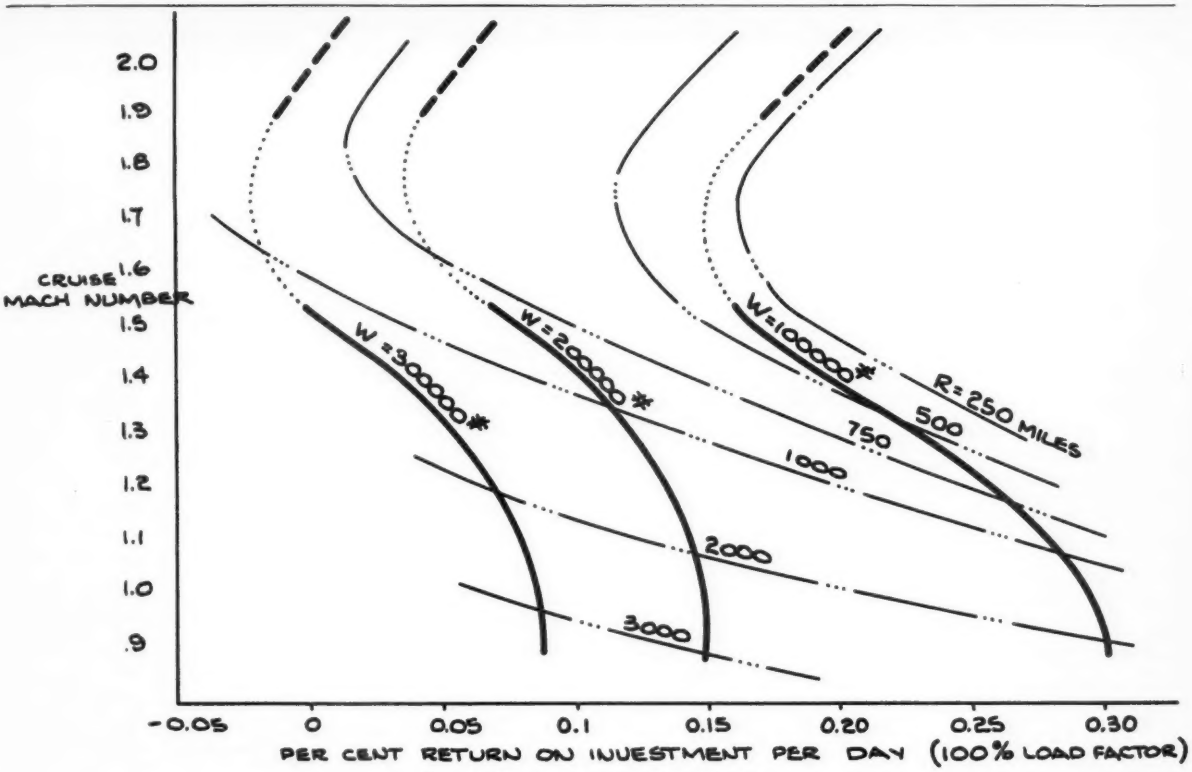

FIG. 9. Per cent return on investment.

At a Mach Number of 1.3, the turbojet-power-plant transport either with or without an afterburner is the cheapest airplane to operate but is still more expensive than a subsonic turbojet design. The subsonic turbojet transport for a cruise Mach Number of 0.9 has a direct operating cost comparable to current propeller-driven transports below an operating range of 2,000 miles and could be used up to range values between 3,000 and 4,000 miles with only a slight increase in cost. It is important to note that the direct operating costs of this family of transports increase as the speed increases and that the supersonic designs are extremely limited with respect to operating range capabilities. Also, an examination of Fig. 7 indicates that the block speeds available for very short ranges, consistent with the operational range capabilities of these supersonic transports, are much lower than the cruise-speed capabilities. In other words, the high cruise-speed capability is inconsistent with the short-range capability.

CONCLUSIONS

Before closing the door to supersonic commercial transports, it is perhaps necessary to take one additional step in an economic comparison. By assuming a given amount of passenger traffic per year, a constant pay load, and a constant utilization per day, the numbers and purchase price of each type of transport can be calculated. This results in the air-line investment in terms of flying equipment required for a given amount of business over a given period of time. By assuming a constant value of indirect operating costs for all types of airplanes and adding these to the direct operating costs obtained from Fig. 8, total operating costs are calculated and subtracted from the income obtained from the assumed passenger miles of traffic. This profit, when divided by the air-line investment, results in a per cent return on investment and is presented in Fig. 9 for the same variables shown in Fig. 8. An examination of these data alleviates in a small manner the undesirable economic trend as Mach Number increases as previously shown in Fig. 8. However, within the scope of operating conditions considered in this study, no reasonable economic case can be made for the supersonic commercial transport.

Instead of leaving the reader with the concept that the supersonic transport is completely untenable because of high operating costs, it is suggested in conclusion that the door may be reopened in a time period 30 to 40 years hence if some of the particular operational limitations imposed in this study are removed. For example, rather unconventional take-off and landing procedures, when applied to a ram-jet transport that cruises at nearly double the operational altitude and speeds considered in this analysis, may result in a commercial transport that could operate at medium ranges at costs approaching the subsonic jet transport. It is impossible, however, at this point to speculate on the reliability, comfort, and safety aspects of this Buck Rogers transport of the twenty-first century.

The Application of Jet Propulsion to Helicopters

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McDonnell Aircraft Corporation

Introduction

The application of jet propulsion to helicopters has undergone study and development in this country for only the last 7 years. The goal of those who aspire to apply jet propulsion is the time-honored aviation adage of less weight, greater pay load, and higher speed. Unlike fixed-wing aircraft, helicopters have not enjoyed the decades of development with reciprocating engines, and ascension to the jet propulsion field includes problems that might have otherwise been solved by earlier development. However, the jet engine has tremendously advanced the aviation industry, and it is only proper that helicopter development take complete advantage of the proved jet propulsion systems.

This paper will endeavor to present the outstanding features and specific applications of both tried and untried jet propulsion systems as applied to helicopters. The aerodynamic features of the helicopter, which may be dictated in part by the particular applications, have been considered only insofar as to stay within practical limits of disc loading, rotor solidity, blade-tip speeds, and profile drag. Since the performance curves included in this paper were taken from both empirical data and unproved calculated data, the future designers should exercise caution in using specific values from this presentation. The graphic illustrations have been selected to establish the relative merits of jet propulsion as applied to helicopters. By going slightly beyond the distinct helicopter classification, it will become apparent that jet propulsion becomes even more attractive when applied to a machine that uses separate propulsion systems for vertical and high-speed horizontal flight.

A few of the tried and untried jet propulsion systems for helicopters are illustrated in the following figures. Fig. 1 shows two propulsion systems, both of which have been used successfully on helicopters. The ram-jet or pulse-jet engine is attached at the rotor-blade tip, and only fuel and ignition lines are required for operation. Individual performance characteristics will be given further scrutiny. Fig. 2 illustrates a rotor-blade tip-section with a turbojet engine installed. A brief discussion of this system is included in the text. Figs. 3, 4, and 5 illustrate the pressure-jet at the blade tip with various means of supplying compressed air to the jets. Fig. 3 shows a pressure-jet system consisting of a reciprocating engine and centrifugal (or axial-flow) compressor, with the compressed air being taken through the rotor hub and out the blades to the tip jets. Fig. 4 illustrates the use of compressor bleed air from a conventional turbojet. Fig. 5 shows the relatively undeveloped ducted-fan type of gas turbine supplying the compressed air to the pressure-jet. Specific performance of each propulsion system is necessary to determine its proper application.

Presented to the New York Section, I.A.S., February 26, 1952.
* Design Engineer.

Ram-Jet Propulsion System

The general ram-jet characteristics, as shown in Fig. 6, describe the basic performance as applied to the blade tip of the helicopter rotor. As may be seen, the specific fuel consumption is the critical item for acceptable helicopter performance and has been the primary target of development programs. As shown on the plot of available thrust per unit area versus tip speed, the ram-jet produces most effectively at the greatest aerodynamically permissible rotor-blade-tip speed, and, to compete with other propulsion systems, this criterion of high tip speed is mandatory. The high tip speed will help determine the aerodynamic design of the

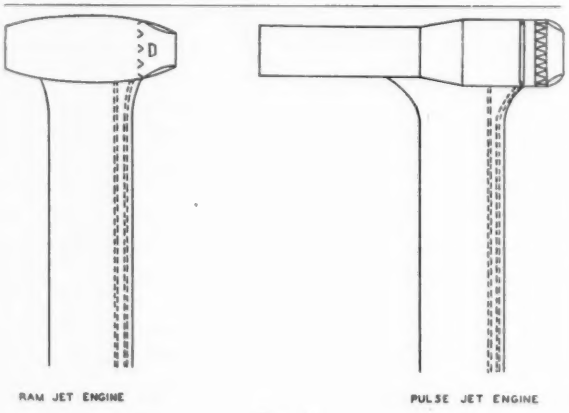


Fig. 1.

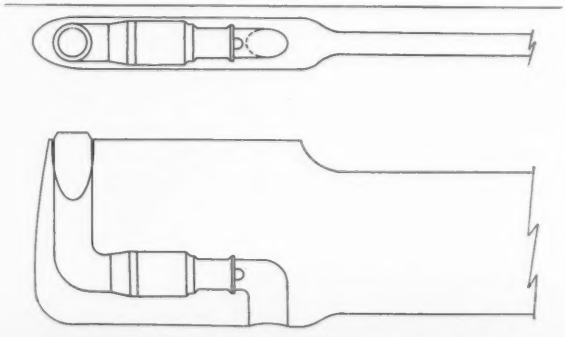


Fig. 2. Turbojet engine installed in the rotor blade tip.

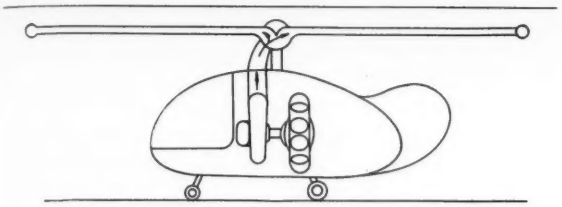


FIG. 3. Helicopter with reciprocating engine, compressor, and pressure-jet tip burners.

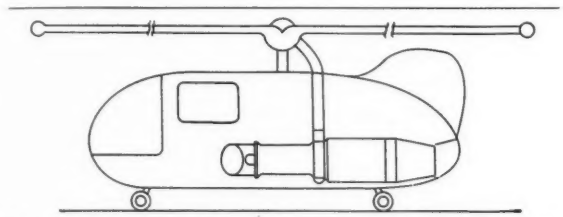


FIG. 4. Helicopter with turbojet engine, compressor air bleed, and pressure-jet tip burners.

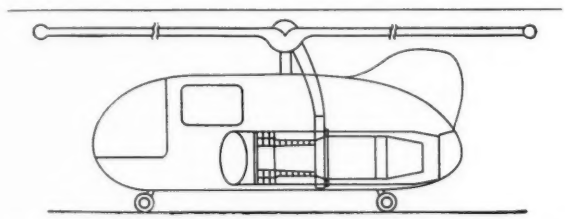
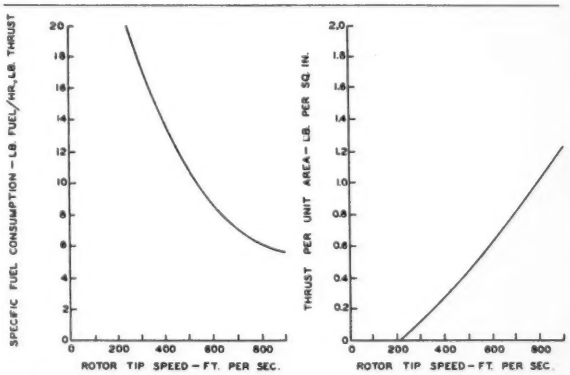


FIG. 5. Helicopter with ducted-fan jet engine, secondary air bleed, and pressure-jet tip burners.

rotor and the final ram-jet helicopter performance. Generally speaking, the rotor with high tip speed is less efficient for helicopter hovering operation, but, by reducing the onset of retreating blade stall, it increases the permissible maximum forward flight speed.

The ultimate performance of the subsonic ram-jet is essentially limited by low pressure ratio created by the pressure recovery at the design blade-tip speed. The inherently low pressure ratio and subsequently high specific fuel consumption have restricted the competitive range of this power plant as applied to helicopters and restricted its application to helicopters having comparatively short periods of operation.

In addition to the characteristics illustrated, the simplicity of the ram-jet and the corresponding low weight are valuable assets to rotor-blade-tip application. The absence of moving parts is inducive to prolonged engine life, and, for production purposes, the number of separate engine parts may be reduced to a minimum. Some conditions experienced in ram-jet application are not advantageous, because, in helicopter forward flight, the ram-jet must operate at various yaw and pitch angles and air speeds with a consequent penalty in thrust and fuel consumption. The decrease in available thrust with changes in pitch has been observed to be as great as shown in Fig. 7. The decrease in available thrust in the example was due to the increase in drag, indicating that the internal performance was not affected. The effect illustrated may become quite detrimental but may be solved by placing the ram-jet on a swivel connector. Attaching the ram-jet at a negative angle of incidence with respect to the blade is a satisfactory solution for powered flight but is extremely detrimental during autorotation. An additional problem that has received only a minimum of study is the uneven distribution of fuel and air due to the centrifugal force field. It is suspected that this may cause an additional penalty in thrust and fuel consumption. Also, the centrifugal g field is capable of distorting the physical shape of a thin-walled ram-jet in such a manner as to appreciably reduce the design performance. Ram-jet design is first determined by theoretical calculation, and the ensuing development program results in the refinements of flameholder, areas, length, fuel injection, and ignition. It is constantly essential to design for the centrifugal forces; consequently, the strength properties of alloy steels at elevated temperatures are a major factor in determining the final weight. As in any other engine, factors of safety and engine life enter into the design criteria. Detailed design of parts such as relatively small integral ignition systems, fuel-cooled flameholders, fuel preheaters, fuel injection systems, and tension skin load-carrying structure are necessary to build a reliable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ROTOR TIP SPEED – FT. PER SEC.
THRUST PER UNIT AREA – LB. PER SQ. IN.
ROTOR TIP SPEED – FT. PER SEC.

FIG. 6. Characteristic performance of a subsonic ram-jet.

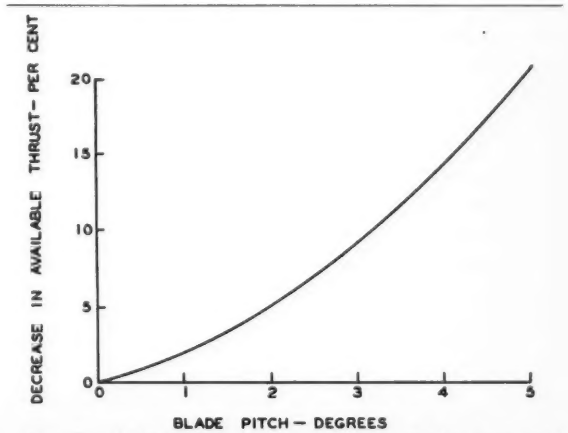
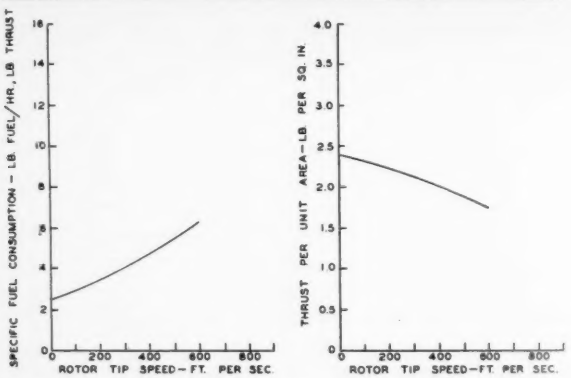


FIG. 7. Variation in helicopter ram-jet available thrust with changes in rotor-blade pitch—ram-jet rigidly attached at zero angle of incidence.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ROTOR TIP SPEED – FT. PER SEC.
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ROTOR TIP SPEED – FT. PER SEC.

FIG. 8. Characteristic performance of a subsonic pulse-jet.

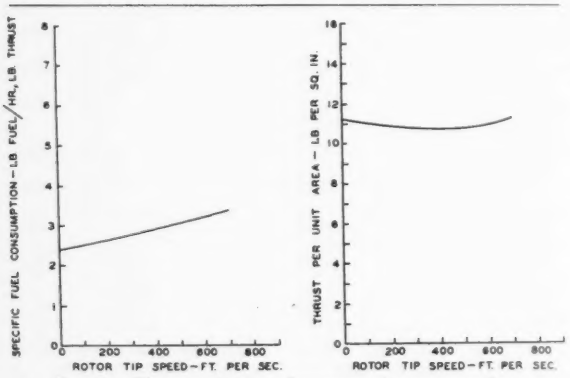
SPECIFIC FUEL CONSUMPTION – LB. FUEL/HR., LB. THRUST
ROTOR TIP SPEED – FT. PER SEC.
THRUST PER UNIT AREA – LB. PER SQ. IN.
ROTOR TIP SPEED – FT. PER SEC.

FIG. 9. Characteristic performance of a pressure-jet.

power plant of minimum weight. The final design is, by aircraft engine standards, relatively simple and readily adaptable to production.

PULSE-JET PROPULSION SYSTEM

A second type of jet propulsion, developed by German engineers and scientists and applicable to helicopters, is the pulse-jet or reso-jet with performance characteristics as shown in Fig. 8. The pulse-jet is essentially a low-speed propulsion unit that, in contrast to ram-jet application, would obligate the helicopter rotor designer to provide the most practical low-tip-speed rotor. The optimum pulse-jet specific fuel consumption (in its practical range) is lower than that of the ram-jet, and the increased thrust per unit cross-sectional area adds further advantage. The decrease in specific fuel consumption is due to the constant volume combustion cycle, although a lower pressure recovery is experienced here than in the ram-jet.

Although the pulse jet is within a reasonable weight category, the moving parts (reeds) are subject to rapid deterioration, and engine endurance is limited. Reed life in excess of 50 hours has been quoted and, even if possible, would appreciably influence pulse-jet practicality. The pulse-jet is also required to function reliably with changing pitch and yaw angles and varying air speed. The probable reduced tip speed lowers the centrifugal loading and lessens the possibility of uneven distribution of fuel and air within the pulse-jet. The advantage of the lower centrifugal field is, however, somewhat nullified by the additional length required by the pulse-jet. A major disadvantage of the pulse-jet is that it is generally conceded to have a higher noise level at a given thrust output than any other form of jet.

TURBOJET PROPULSION SYSTEM

Application of the turbojet engine to the helicopter is problematical at this time. Extremely large helicopters of the order of 50 tons gross weight may eventually use turbojet engines mounted in the rotor-blade tip. The specific fuel consumption is quite reasonable, but the weight and large cross-sectional area require large and highly stressed blades. Since the turbojet has rotating parts, the gyroscopic moments imposed on the rotor blades would be large and would possibly introduce unsatisfactory flying characteristics. The bearings of the turbojet would be required to withstand either excessive thrust or side loads unless the centrifugal loads were reduced by using extremely large diameter rotors. At the present stage of helicopter development, the turbojet engine is not particularly applicable. The installation with the turbojet in the fuselage has been included in the next section.

PRESSURE-JET PROPULSION SYSTEM

The fourth type of reaction jet located at the blade tip, known as the pressure-jet, uses compressed air ducted through the rotor hub and blades to the tip burner or nozzle. Three of the possibilities were illustrated in Figs. 3–5.

The compressed air ducted to the blade tip may be used for combustion or may be simply exhausted through a nozzle providing the jet thrust. The exhaust from turbojet engines, which is frequently a pressure ratio of the order of 2, may be transferred to the rotor-blade tip and exhausted. Exhaust temperatures of even 1,000°F. would impose severe structural problems in the rotor blades and would eliminate the use of aluminum and adhesives for fabrication. The ducted fan engine, which could combine the secondary fan air with the exhaust air, would probably give satisfactory air temperatures; however, the pressure ratios are low for such engines in their present stages of development. The present trend of pressure-jet application to helicopters is to use the proved axial-flow or centrifugal compressor driven by reciprocating or gas-turbine engines. The compressed air is used for combustion as the increase in thrust is necessary to make such a helicopter competitive with conventional helicopters.

The fuel-burning pressure-jet will have basic performance characteristics that depend largely upon the pressure of compressed air and the final combustion temperature. The approximate characteristics of a pressure-jet operating at a compressed air pressure ratio

of 3 and combustion temperature of 3,500°F. is illustrated in Fig. 9. It is obvious that the increased pressure ratio (assuming comparable combustion temperatures of the ram-jet and pulse-jet) has decreased the specific fuel consumption to a fraction of that given by ram- or pulse-jet engines.

A further reduction in specific fuel consumption is possible by using compressed air of greater pressure ratios. There is a practical limit of pressure ratios beyond which the increased weight of compressor and power plant will overcome the advantages of reduced specific fuel consumption, and such a limit is believed to be at pressure ratios of the order of 4.

The second advantage of high thrust per unit of cross-sectional burner area provides concentrated power at the blade tip with little penalty of size and weight. The low weight results in correspondingly fewer structural problems, and the reduced size gives reduced profile drag, which is particularly desirable for satisfactory autorotation properties. The curve of thrust per unit area versus rotor-tip speed (Fig. 9) indicates that the thrust is essentially independent of tip speed, so that, in contrast to the ram- and pulse-jet, the design tip speed of the rotor need not be dictated by the tip jet. Further advantages of the pressure-jet configuration include no internal losses during autorotation if the air duct is closed and no adverse effects on the internal burning due to pitch and yaw angles.

There is no apparent limitation on the size helicopter that may be powered by pressure-jets. The pressure-jet thrust required is a function of the diameter squared as the rotor size is increased. The duct area through the blade available for compressed air also increases as the diameter squared. Therefore, if comparable pressure ratios, jet velocities, tip velocities, and combustion temperatures are assumed, the pressure-jet is capable of supplying power for rotors of the foreseeable practical sizes. The limitations on the size of practical pressure-jet helicopters are presently the compressors and engines available and suitable for such purposes.

At the present stage of development, only the reciprocating or gas-turbine engine is qualified to drive the compressor for pressure-jet systems. The turbine-driven compressor has lower weight per horsepower, and, for the sizes in the 500-horsepower range, the fuel consumption is slightly greater than for the compressor and reciprocating engine combination. As shown in Fig. 10, the pay load and range are both superior for the compressor with gas-turbine drive. For engines of increasingly greater horsepower, the specific fuel consumption becomes more nearly comparable, which adds further to the advantages of the gas-turbine engine.

Providing air for pressure-jets by bleeding off the compressor of a turbojet engine may serve as an interim solution, although a rather inefficient one, if only the compressed air and not the thrust is used.

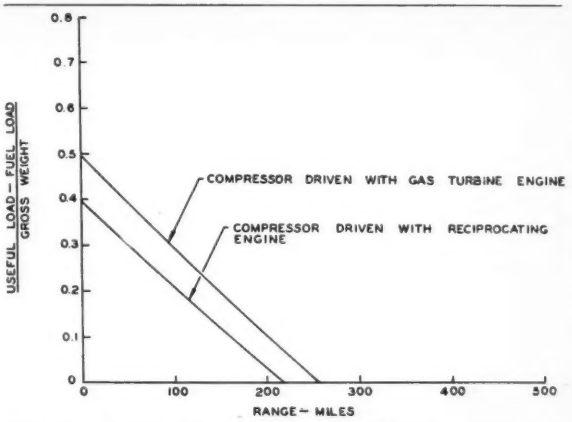

FIG. 10. Comparative performance of engine-compressor combinations for a pressure-jet helicopter.

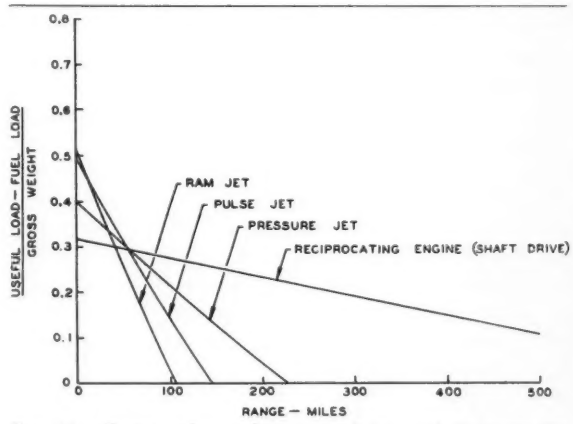

FIG. 11. Comparative performance of jet- and reciprocating-engine helicopters.

COMPARATIVE PERFORMANCE OF JET- AND RECIPROCATING-ENGINE HELICOPTERS

The merit of any helicopter design is ultimately judged by what the machine will do for the customer. In judging or comparing helicopters, emphasis may be placed on one or more performance characteristics—flight speed, endurance, range, initial cost, operating cost, pay load and serviceability. It may be said with certainty that either range or pay load or both will be prime requisites for helicopter design, and, consequently, the jet- and reciprocating-engine helicopters have been compared on this basis. The performance curves in Fig. 11 were arbitrarily chosen for a helicopter of approximately 5,000 lbs. gross weight. It should be clearly understood before examining the curves and drawing rigid conclusions that helicopters of greater or lesser gross weight will have similar trends but may have pronounced changes in the factors of pay load and range. However, Fig. 11 does describe the advantages and limitations of jet propulsion as applied to helicopters.

The subsonic ram-jet propulsion system, because of its present relatively high fuel consumption, has comparatively limited range. For short-range work, the

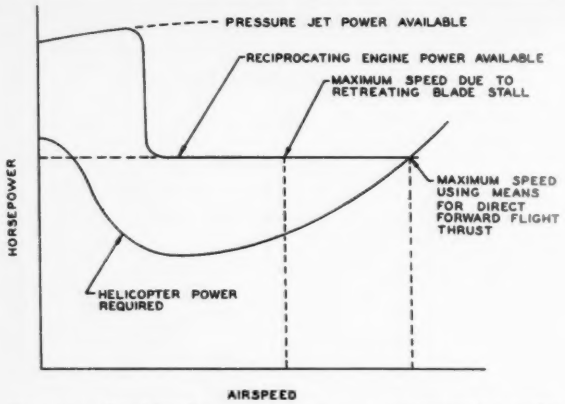
PRESSURE JET POWER AVAILABLE
RECIPROCATING ENGINE POWER AVAILABLE
MAXIMUM SPEED DUE TO RETREATING BLADE STALL
MAXIMUM SPEED USING MEANS FOR DIRECT FORWARD FLIGHT THRUST
HELICOPTER POWER REQUIRED
HORSEPOWER
AIRSPEED

FIG. 12. Combination pressure-jet and reciprocating-engine helicopter.

great pay load with respect to its total weight is creditable. In design, it is probably the utmost in simplicity and, with the low cost, would be attractive for mass production and expendability. Such a helicopter requires little service or few skilled technicians in operation. The elimination of the antitorque rotor is a progressive achievement that effects more in simplification of the helicopter than in weight-saving, since directional control rudders are still required. There is a saving of approximately the equivalent of 7 to 8 per cent of the required horsepower that would be used by a single-rotor, conventional helicopter. Twin-rotor helicopters do not require antitorque rotors since the rotors turn in opposite directions, and, thus, the torque reaction of each is cancelled.

The pulse-jet helicopter has slightly greater range than the ram-jet due primarily to its reduced specific fuel consumption. This engine is about equal in simplicity but requires more maintenance than the ram-jet. The static thrust characteristic makes this engine more convenient for rotor starting and acceleration. Again the antitorque rotor is eliminated, and the design has low initial cost, which encourages quantity production and widens what might otherwise be a narrow field of application.

The application of the pressure-jet to the helicopter increases the range appreciably when compared to the ram- and pulse-jet; however, for maximum range it will not compete with helicopters using shaft-driven rotors (Fig. 11). The compressor and reciprocating engine (assumed for this comparison) necessary for pressure-jet operation and the ducting of compressed air to the rotor-blade tips introduce weight and design problems different from those associated with ram-jet and pulse-jet systems. For this hypothetical helicopter of 5,000 lbs. gross weight, the pay load for short-range operation is considerably greater than that for the reciprocating-engine helicopter and less than that for helicopters with ram- and pulse-jets. For a given size, the pressure-jet is capable of applying, at the least, five times as much power to the rotor-blade tip as either the ram- or pulse-jet and will do this at a fraction of the specific fuel consumption. The potential applications of such a jet system seem to extend beyond the range afforded by either ram-jet or pulse-jet. By applying the rotor power at the blade tips, the antitorque rotor is again eliminated. The overall comparison of the four types of power systems for helicopters indicates that, for operation at ranges less than 75 miles, the jet engine is feasible for helicopters in the 5,000-lb. gross weight class. If it were the purpose of this paper to really sell the idea of jet propulsion for helicopters, the relative performance, as shown in Fig. 11, would have been for helicopters of 15 to 20 tons gross weight. Generally speaking, the pay load of the pressure-jet helicopter for short-range operation will be considerably greater as the gross weight increases.

For the ram-jet and pulse-jet helicopters with a gross weight of the order of 20 tons, the required engine performance would necessitate propulsion units of impractical size or number. The reciprocating engine with gear transmission, as used today, increases in weight at least in direct proportion, if not in greater proportion, to the gross weight. Therefore, the performance curves of Fig. 11 will spread for helicopters of increased gross weight, and the pressure-jet helicopter will become particularly advantageous for such uses as short-haul cargo transportation, construction of bridges and dams, and "ship to shore" transportation. The ram-jet- and pulse-jet-powered helicopters are attractive where short-range operation and low initial cost are the prime considerations. The reciprocating engine will continue to serve as a reliable and efficient power installation for long-range helicopters of contemporary size and gross weight.

JET PROPULSION FOR PART-TIME OPERATION

It seems appropriate to extend the scope of this paper to include a discussion of the application of jet propulsion to the part-time power operation of rotors.

It is well known from autogyro experience that an autorotating rotor will serve as a lifting means as the fixed wing serves the airplane. Helicopter forward flight speed is frequently limited by the retreating blade stall—a characteristic aggravated by the use of the rotor for providing forward thrust. The forward flight speed of the helicopter may be appreciably extended by the temporary application of jet propulsion to the rotor for take-off, climb, and landing, in combination with an additional means of providing direct thrust to the aircraft for cruising flight.

By examining a typical power-required curve for a rotary-wing aircraft of this type, it may be seen that a power-available curve of similar contour would result in economical operation (Fig. 12). The power-available curve of a reciprocating engine is excessive at forward flight speeds, because the hovering and climb conditions dictate the power required. It would be desirable to provide a power-available curve that more nearly parallels the power-required curve. By using

the pressure-jet system for hovering and low forward speed flight, and then converting to reciprocating-engine power and propeller thrust, the power-available curve is "tailored" to the power-required curve. The size of reciprocating engine required is thereby reduced from that required for a conventional helicopter of the same gross weight. Since the pressure-jet system, as applied to this type of machine, is in operation for hovering, climb, and the initial forward acceleration only, the total operating time and related fuel consumption are held to a minimum.

Further, part-time use of jet propulsion may be applied by using a turbojet engine or ducted-fan jet engine rather than the reciprocating engine. With the turbojet engine, the compressed air would be bled from the compressor for pressure-jet hovering, climb, and low forward speed operation, and jet thrust would be used for high-speed flight. A similar situation exists with the ducted-fan jet engine. Variable exit nozzles would be desirable on both the turbojet and ducted-fan installations. A rotary-wing aircraft using a turbojet or ducted-fan engine would not have idle compressors, propellers, or gear boxes in any flight condition. The reciprocating engine, compressor, and propeller combination does have either the compressor or propeller idle during flight. The penalty of transporting an idle power-plant component may be lessened by the design speed of the aircraft, since the use of turbojet thrust for speeds of the order of 200 m.p.h. would be less desirable than propeller thrust. The ducted-fan jet engine, when fully developed, should approach the efficiency of the turbine-driven propeller system and, as such, might prove to be a particularly desirable combination.

Summary

Helicopters with rotors driven by jet propulsion have been successfully flown for several years. The principal types of jet engines used were the ram-jet, pulse-jet, and pressure-jet. Profitable use of these jet-propelled helicopters is limited to those applications where large pay load, short range, and low manufacturing costs are the outstanding requisites. Of the three types of jet engines, the pressure-jet has the best range with a given pay load, the advantage increasing with increased gross weight. The jet-engine helicopter, as known today, does not compete with the reciprocating-engine helicopter if extensive range is required but must rely on greater pay load and, particularly for ram- and pulse-jet engines, on simplicity of design and fabrication as competitive qualities.

Jet propulsion, particularly the pressure-jet system, as applied to rotary-wing aircraft for part-time operation can provide a source of great rotor power during hovering, climb, and low-speed forward flight. The pressure-jet system will give rotor horsepower that is 40 to 50 per cent greater than the engine used to drive the compressor. Although the compressor is added, the conventional gear box is eliminated. The ducted-fan engine with variable exit nozzle would conveniently provide compressed air for rotor-tip jet thrust or, using an autorotating rotor, would provide thrust for forward flight.

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Use of a Low-Density Core Material in Aircraft Structures

RAYMOND J. MOORE* and JOHN M. ELLISON*

Northrop Aircraft, Inc.

SUMMARY

This paper covers the use of a low-density core material in aircraft structures. The results of tests run at low temperature and pressure are given along with the reaction of bonded Styrofoam structures to high-frequency vibration. The cost and weight advantages of this type of structure are covered, and, in this regard, a direct comparison is made with interchangeable all-metal structures.

INTRODUCTION

FOR A NUMBER OF YEARS, the skin on aircraft was primarily a covering, or fairing, for aerodynamic purposes. With the advent of high-speed flight, airfoils have become thinner. It has become necessary to use the skin for structure, as well as fairing. In general, this meant that the skin got thicker, more internal members were necessary to stabilize the skin for stress purposes, and the surfaces became heavier overall.

In the past decade, with the widespread development of avionics, we have experienced an ever increasing percentage of the gross weight being devoted to safety and operational electronic gear. This trend, necessary though it is, results in only one thing—a decrease in pay load. One of the possible means of making up this weight deficit lies in reducing basic airframe weight without jeopardizing structural integrity.

STRUCTURAL EFFICIENCY

The most efficient structure is one where as much of the weight as possible is stressed as high as possible. The most efficient location for stressed weight is in the skin, where the bending forces can be more effectively handled. The only other stresses that need be accounted for, other than the shear in the plane of the skin, are the shear stresses in the cross-sectional direction, both torsionally and longitudinally. To prevent buckling, it is necessary to stabilize the skin to carry both bending and shear loads. An effective means of stabilizing the skins on wing, empennage, and control surfaces is through the use of a core material bonded to the skins. In addition to stabilizing the skin, the core should be as light as possible and still carry all, or most of, the cross-sectional shear loads. For producibility, the core should be such that it can be easily fabricated and bonded.

In addition to general structural considerations, the use of a low-density core design is frequently indicated for dynamic and aerodynamic reasons. An example of this is a typical thin high-speed control surface that must be mass-balanced about its hinge line and still be fully contained within the airfoil throughout the full control movement. It is obvious that the less the surface weighs, the easier the problem becomes.

APPLICATION OF LOW-DENSITY CORES

With the above thoughts in mind, the Special Weapons Division of Northrop Aircraft instigated a program aimed at providing a new, economical, lightweight structure. Such a structure has been successfully carried through the development stages and is now being used extensively on a classified project. In addition to control surfaces, structure of this type is suitable for leading and trailing edges and secondary structure generally. Recent tests indicate a strong possibility of use as primary structure in wings and stabilizers. Typical examples are shown in Figs. 1 and 2. Basically, it consists of a foamed polystyrene core, sold commercially under the name of Styrofoam, bonded to thin sheet-metal skins. Internal members are kept to a minimum, being used only where necessary to carry concentrated local loads. Concurrently with the design program, it was necessary to develop a bonding agent that would be satisfactory under all operational conditions and, at the same time, be inexpensive and simple to apply. Such an adhesive was developed by R. Pease, Northrop Process Engineer.

Styrofoam, a Dow Chemical Company product, is a white multicellular plastic foam produced by the expansion of a polystyrene approximately 40 times. Since its shear strength varies from 25 to 45 lbs. per sq.in. for densities from 1.6 to 2.0 lbs. per cu.ft., it can be seen that it definitely has its structural limitations. However, good design can make it go a long way into the primary and secondary structural fields. Styrofoam can be machined with common wood-cutting tools to a surprising degree of accuracy. That, together with its low compressive strength, makes it ideal for aerodynamic surfaces, since, if the core is cut slightly oversize, it can be pressed down to the correct size in the bonding process. As far as producing a satisfactory bond is concerned, mere contact pressure at room temperature is all that is required.

TEST RESULTS

A series of stringent 10-hour high-frequency vibration tests under 25 per cent limit load has shown no adverse effect on either the core or the bond. Shear tests have been run on panels that had first been ex-

* Design Engineer.

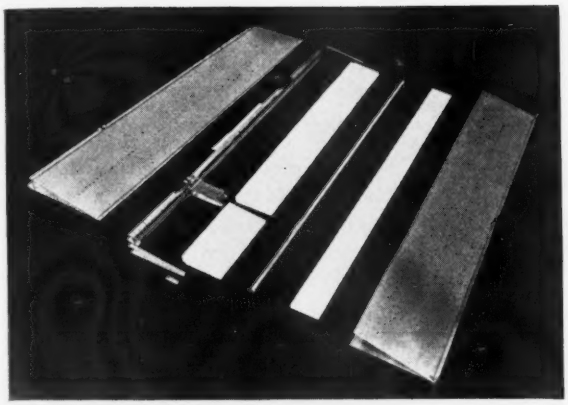

FIG. 1. Elevon.

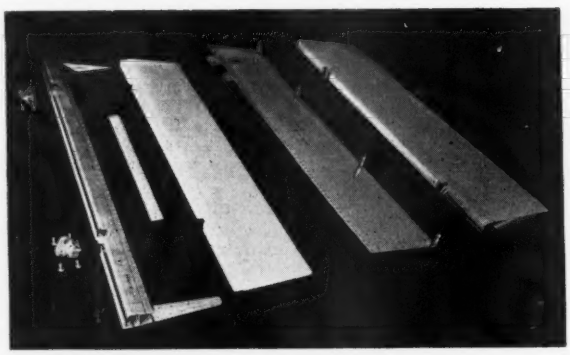

FIG. 2. Rudder.

ASSEMBLY	TYPE OF STRUCTURE	WEIGHT	COST
WING TRAILING SECTION	CONVENTIONAL — ALL METAL	105 LBS.	$1312.00
	STYROFOAM	55 LBS.	$149.00
ELEVON	CONVENTIONAL — ALL METAL	19 LBS.	$1050.00
	STYROFOAM	11 LBS.	$230.00

FIG. 3. Weight and cost comparison.

posed to pressure equivalent to 60,000-ft. altitude and −65°F. Low pressure and temperature have no apparent effect on the structure. The average results of the above tests are shown in Fig. 4. It was observed during these tests that, with no load and the specimen at −65°F. and sea-level pressure, a compressive stress of about 4,400 lbs. per sq.in. was indicated by strain gages mounted on the lower tension surface. This stress could develop because of a large increase in modulus of elasticity, along with the difference in coefficients of thermal expansion of Styrofoam and aluminum. If this is assumed to be correct, then the skin stresses under load would be affected by the phenomenon. When undergoing static tests, panels of the type shown in Fig. 1, with 0.016 75 STAL skins, consistently developed skin stresses greater than 40,000 lbs. per sq.in.

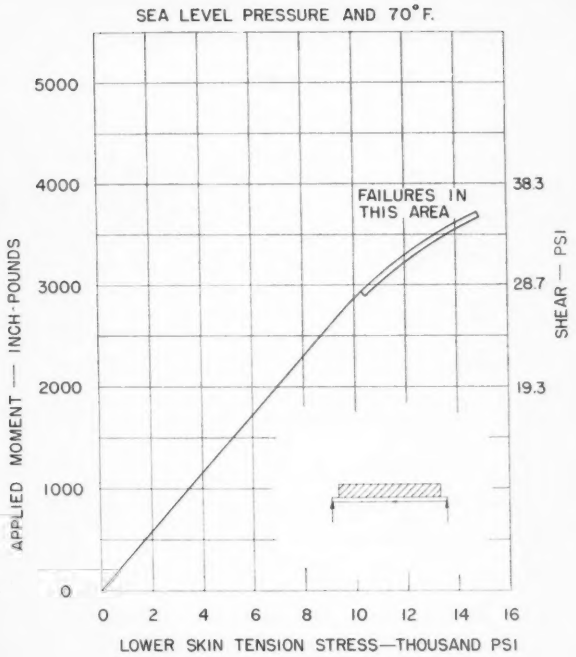

FIG. 4. Shear and moment versus stress.

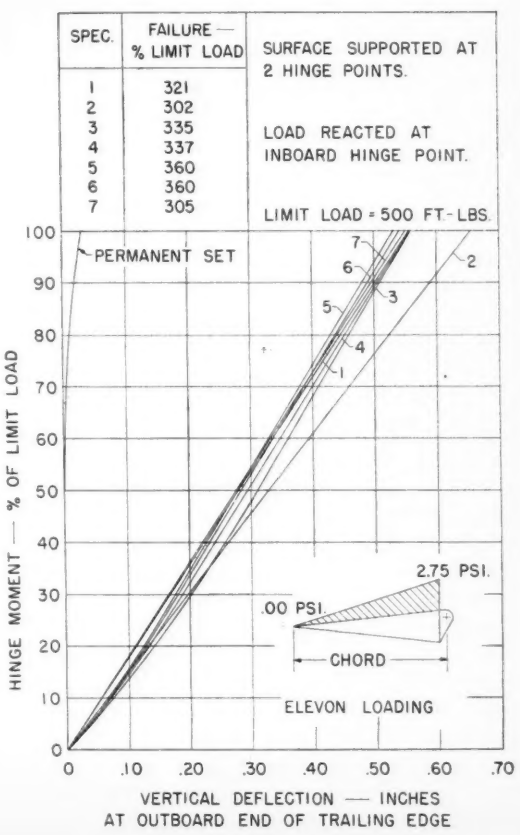

FIG. 5.

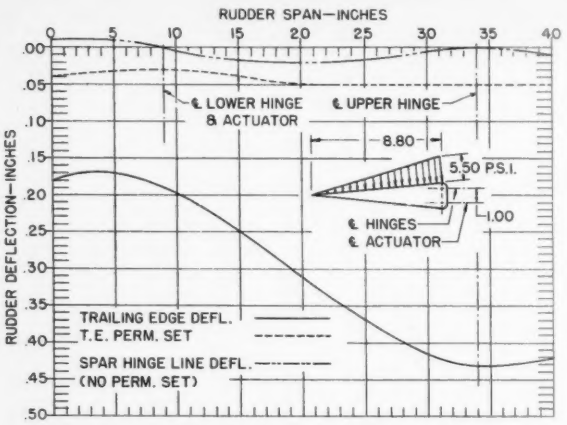

FIG. 6. Rudder deflection at limit load (static test).

before failure. The deflection curves and points of ultimate failure of these panels, shown in Fig. 5, illustrate the consistency of this type of structure. Tests run on the rudder produced similar results and are shown by an average curve in Fig. 6. Ultimate failure of the test rudders averaged 190 per cent of limit load.

ECONOMIC ASPECTS

It is in the field of economics that low-density sandwich construction of this type comes into its own. Because of existing circumstances at Northrop, it was possible to make direct replacements of conventional assemblies with Styrofoam structures and thus get a complete and accurate weight and cost comparison. Fig. 3 shows the results found for both fixed secondary structure and control surfaces. The costs shown include tooling amortization over 100 units in each case.

There are large-scale savings, weightwise as well as financial, to be derived from proper utilization of this type of structure. The main contributing factors are the reduction in the number and gage of detail parts and the simplification of final assembly.

Guest Editorial

(*Concluded from page 21*)

"We have an atomic-powered submarine under construction. I hope that some of the future carriers of the *Forrestal* class will also be atomic powered. And, while we are right on that subject, how quickly are you people going to be able to provide us with a nuclear-powered airplane?

"It takes a long time to translate a new idea into a new airplane and to get a new airplane into production. In round figures, it takes 7 years and costs $75,000,000. The same is true of new type of ships and complicated weapons of various sorts. Therefore, I am not talking about the airplane of tomorrow or next year. The ones of which I speak may be just merely a glint in the eye of some young scientist or engineer right here in this room. Possibly he has sketched something roughly on his drawing board, or probably he has just filled his first notebook with mathematical calculations.

"Whatever stage these plans may be in today, it is essential that we explore their possibilities thoroughly if we are to have continued progress in aeronautics. One fleeting idea properly developed could turn out to be a most important factor in our national defense and in the development of commercial aviation, which will come after the peace of the world has been made secure.

"The door is wide open for ideas insofar as guided missiles are concerned. In 1945, we had only one missile. It was manifestly inferior to the German missiles. Today, we are beginning to get operational missiles, but there is plenty of room for improvement

"As compared with piloted aircraft of the highest-speed jet variety, the supersonic guided missile is a new and much more difficult development problem. This is primarily because the missile has no human pilot to feel its troubles and make corrections and to tell the designers.

"To breach this gap of communications with robots, it is necessary to have missile engineering design thought through and tested very completely. Thus we need not only more creative genius in missile design but also genius in the devising and interpreting of design tests.

"As a nation devoted to respect and protection of individual dignity, we oppose the doctrine of the expendability of the individual. Eight years ago, the Japanese Empire launched against us a better guided missile than we have yet been able to develop under our own ground rules. We reject the kamikaze principle and choose rather to devise machinery to perform such tasks, and we must stick to our own ground rules and principles if we are to win. We cannot hold the lives of any of our people cheaply if we are to succeed in the establishment of a lasting peace. We cannot sacrifice even so many as one of our fighting men on the altar of expediency if we are to retain any hope of convincing that part of the world now under Communist domination that the ways of freedom and the ways of democracy are the true way of life.

"American ingenuity and American production have managed to win for us all of our previous wars. If we expect to be able to repeat that performance at a future date, which will certainly be none of our own choosing, we cannot afford to rest on our oars. What we need to be doing is asking up and down the halls of science:

"Is there an idea in the house?"

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350	The Effects on Dynamic Lateral Stability and Controllability of Large Artificial Variations in the Rotary Stability Derivatives—R. O. Schade, O. B. Gates Jr., and J. L. Hassell, Jr.	0.50	0.85
349	Diffuser Efficiency of Free-Jet Supersonic Wind Tunnels at Variable Test Chamber Pressure—Rudolf Hermann.	0.50	0.85
348	Boundary-Layer Studies on a Sailplane—August Raspet.	0.50	0.85
347	The Calculations of Spanwise Loadings for Oscillating Airfoils by Lifting-Line Techniques—M. A. Dengler and Martin Goland.	0.50	0.85
346	Reduction of Gun-Gas Explosion Hazard in Combat Aircraft—J. J. Horan, J. R. Onderdonk, and E. Witkin.	0.50	0.85

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Preprint Department, Institute of the Aeronautical Sciences

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Air Turbine Refrigeration | Heat Transfer Equipment | Electric Actuators | Gas Turbines | Cabin Superchargers | Pneumatic Power Units | Electronic Controls | Cabin Pressure Controls | Temperature Controls

News of Members (Continued from page 19)

time was made an A.F.A. Honorary Life Member, was cited for his achievements in the air-borne radar field as an outstanding contribution to commercial aviation. A program for research and development of air-borne radar, APS-10, was started at American more than 5 years ago and was continued for several years. The project was dropped for a couple of years because of the expense involved; however, it has since been put into operation again.

▸ **Douglas Campbell** (A.M.), Vice-President and General Manager, Pan American-Grace Airways, Inc., was elected Chairman of Traffic Conference #1, International Air Transport Association. Conference #1 is the I.A.T.A.'s traffic conference in the Western Hemisphere.

▸ **Dr. Luigi Crocco** (A.F.), Goddard Professor, Guggenheim Jet Propulsion Center, Princeton University, was appointed to the Advisory Board of Reaction Motors, Inc.

▸ **C. L. Egtvedt,** I.A.S. Fellow and Founder Member, Chairman of the Board, Boeing Airplane Company, was awarded a five-diamond pin symbolizing 35 years of service with Boeing Airplane Company. The presentation was made by William M. Allen, Boeing President. Mr. Egtvedt joined the company a few months after it had been formed by William E. Boeing.

▸ **Frank W. Godsey, Jr.** (M.), Manager of the Electronics, X-Ray, and Air-Arm Divisions, Westinghouse Electric Corporation, was awarded the Westinghouse Order of Merit, the company's highest award for distinguished service, at an informal luncheon on June 25.

▸ **N. E. Halaby, Jr.** (M.), who, for for the past 3 years, has been engaged in assignments with the Department of Defense and the Mutual Security Agency on North Atlantic Treaty and Mutual Security Program matters, is now in the office of Frank C. Nash, Assistant to the Secretary for Internal Security Affairs. Mr. Halaby is serving as Mr. Nash's Deputy for European Mutual Security Affairs pertaining to the Department of Defense and will work with the various elements in the Pentagon concerned with NATO and the Mutual Security Program, the Office of the Director for Mutual Security, the Mutual Security Agency, and the Department of State.

▸ **Dr. Jerome C. Hunsaker,** I.A.S. Honorary Fellow and Founder Member, retired from the faculty of the Massachusetts Institute of Technology at the end of the 1951–1952 academic year last July 1. Dr. Hunsaker, who was the Head of M.I.T.'s Department of Aeronautical Engineering from 1933 to 1951, will continue his association with M.I.T. as Lecturer in Aeronautical Engineering.

PROMOTED BY B.O.A.C.

Thomas D. R. Carroll (M.) was recently named by British Overseas Airways Corporation as Senior Technical Officer (Aircraft). In this capacity, he is responsible for all matters relating to aircraft design and for advising the corporation on all design problems and specifications. Mr. Carroll, who is an Associate Fellow of the Royal Aeronautical Society, was formerly Stress Officer in charge of B.O.A.C.'s Stress Section.

ELECTED PRESIDENT

William J. Carry (M.) has been elected President and a Director of General Laboratory Associates, Inc. He was formerly a Vice-President of The BG Corporation, which he joined in 1939. Prior to that year, Mr. Carry had been with Fairchild Engine and Airplane Corporation and with Wright Aeronautical.

▸ **Joseph Marin** (M.), Professor of Engineering Mechanics and Research Professor of Engineering Materials, was recently awarded a Fulbright Professorship to lecture at the Technological Institute at Trondheim, Norway, for the 1952–1953 academic year.

▸ **Miss Bernetta A. Miller,** an I.A.S. Historical Associate Member, recently observed the fortieth anniversary of her first solo flight in a Moisant monoplane at Garden City, L.I., N.Y., prior to qualifying for F.A.I. Aviator's License No. 173, September 25, 1912. Miss Miller is said to be the third American woman to have received a pilot's license.

▸ **Major General Donald L. Putt,** U.S.A.F. (H.M., A.F.), assumed his full-time duties as Vice-Commander, Air Research and Development Command, Baltimore, Md., on June 19. Assigned to that post last January, General Putt was given the additional assignment of Acting Commanding General, Wright Air Development Center, A.R.D.C., Wright-Patterson Air Force Base, Ohio. Brigadier General Albert Boyd, who since last January served as Vice-Commander of the Wright Air Development Center, was appointed Commanding General of that installation.

▸ **George Sonnemann** (T.M.), Assistant Professor of Aeronautical Engineering, Drexel Institute of Technology, is taking a year's leave of absence from Drexel Institute to work as a Research Associate with the University of Michigan's Engineering Research Institute. At the same time, Professor Sonnemann will attend school and complete work for his doctorate in Engineering Mechanics.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of I.A.S. members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

L. R. Barr (M.), Assistant Division General Manager, Romec Division, Lear, Incorporated. Formerly, Chief Engineer, Lear's Romec Division.

Captain J. O. Biglow, U.S.N. (M.), Bureau of Aeronautics Representative, Department of the Navy, El Segundo Plant, Douglas Aircraft Company, Inc. Formerly, Overhaul and Repair Officer, Naval Air Station, Corpus Christi, Tex.

(*Continued on page 60*)

American Helicopter Society News

Fort Worth

The first meeting of the new Southwestern Region of the American Helicopter Society was held in Fort Worth, May 28. Over 200 members and guests heard a "Report on the 8th Annual Forum of the American Helicopter Society" and the "History of the Bell Helicopters."

Robert R. Lynn, Performance Engineer, Bell Aircraft Corporation's Helicopter Division, gave a report on the forum. He expressed the opinion that the 8th Annual Forum showed improvement over past forums in two ways: the papers were of better quality, and the attendance at the technical sessions showed an increase.

Bartram Kelley, Chief Engineer, Bell's Helicopter Division, presented the first of three parts on the "History of the Bell Helicopter." He spoke on the "Development of the Model 30," which had its beginning in 1929 when Arthur Young began to experiment with model rotors. Mr. Kelley showed historical movies taken in the summers of the early thirties when he helped Mr. Young with his experiments. The setting for the pictures was at the Young's country home in Paoli, Pa. The through breeze caused by opening the doors on the opposite sides of the red barn furnished them with a wind tunnel for their early experiments. It was from these tests that they developed a flying model that brought them the signal from Lawrence Bell in 1941 to go ahead with the Bell Helicopter Project. In 1942, they produced the first full-size flying helicopter, which was called the Model 30-1. In 1942, Floyd Carlson made the first flight in the ship, which was the beginning of a series of test flights.

George Linnabery, Group Engineer, Bell Helicopter Division, related the second part of the history, "Engineering the Model 47." The Model 47 was the next Bell ship to be designed after the Model 30. A small staff of draftsmen, engineers, shop workers, mechanics, and pilots worked as a team to produce the first of the 47's. Parts were made from freehand sketches and vellum drawings, with firsthand information from the engineers to fill in the gaps. The shop and engineers often worked all night to supply a part needed for the next day's test flight. As a result of this united effort, Bell Aircraft had the first production certificate for a C.A.A. licensed helicopter NC1H, March 8, 1946.

Mr. Linnabery said that the lunch hours served as a general conference for the pilots, mechanics, and engineers to discuss the problems of their helicopter. During these discussions, the knives, forks, and plates were transformed into helicopters and rotors. It was here that the plans for a separate Helicopter Division were first conceived.

John Buyers, Jr., Engineering Supervisor, Experimental Section, Bell Helicopter Division, concluded the history with part three, "Recent Developments and Prospects for the Future." In his talk, he outlined the present projects that the Helicopter Division is now carrying on at its new plant in Fort Worth. A few of the projects that he mentioned were: The Model 48, an eight-place helicopter for the Air Force; the Model 54, a high-altitude helicopter; the new Anti-Submarine Warfare Helicopter; and the convertiplane. Mr. Buyers also indicated that the Experimental Section was presently investigating the use of hydraulic control systems and methods to improve stability.

In conclusion, Mr. Buyers pointed out that trends for the future called for larger helicopters and a sharp increase in the use of this equipment in the commercial transportation field. He also predicted that the development of the convertiplane will make higher speeds possible for rotor-type aircraft. The convertiplane combines the desirable characteristic of the helicopter to land in a small area with the faster speeds of the propeller-driven planes. This unique combination will be a great step to help man in his battle to save time.

JOHN D. BEADLING
A.H.S. Vice-President—
Southwestern Region

Contributors to American Helicopter Society News are urged to keep in mind that it takes about 6 weeks for copy to get in print. This page needs material on the activity of regional groups and individual members, but it must be in the hands of the publicity chairman not later than the 5th of the month to appear in the issue of the second month following. Address contributions to Claude O. Witze, Piasecki Helicopter Corporation, Morton, Pa.

St. Louis

Approximately 50 A.H.S. members and McDonnell Aircraft Corporation's Helicopter Engineering Division engi-

A.H.S. St. Louis Meeting: *Major William P. Mitchell, U.S.M.C. (center), who spoke at the June 23 meeting, is shown with (left) C. R. Wood, Jr., McDonnell Aircraft Corporation's Chief Helicopter Test Pilot and Customer Service Manager, and (right) C. H. Hurkamp, Chief Engineer, McDonnell's Helicopter Division.*

neers heard an informal discussion of Marine rotary-wing combat operations by Major William P. Mitchell, U.S.M.C., HMX-1, M.C.A.S., Quantico, Va., on June 23, 1952.

Major Mitchell told of his Korean helicopter operations, showed movies of those operations, discussed helicopter maintenance problems, and gave his views of helicopter requirements for future transport helicopters. An experienced pioneer helicopter pilot, he was one of the first assigned to the Marine experimental helicopter squadron HMX-1. He has been active in tests of helicopters for Marine assault and other transport operations and recently returned from duty in Korea as Executive Officer of the first Marine transport helicopter squadron HMR-161.

Major Mitchell discussed many of the Marine's Korean transport helicopter missions—Operations Windmill, Summit, Bumble Bee, Muletrain, Mousetrap, etc. Some of Major Mitchell's personal opinions, not necessarily the opinions of the U.S.M.C., are that the helicopter (1) performance must be improved, (2) navigational aids must be provided, (3) must be more rugged with reduced maintenance and replacement of parts, (4) must be capable of operating in high winds, (5) must be built for the average pilot, (6) must be fitted for armor and armament, (7) must be capable of carrying loads externally as well as internally, (8) must have night-lighting provisions, (9) must have automatic blade folding and ability to taxi with blades folded, (10) must be capable of operations in all weather conditions, (11) should be the best V.F.R. aircraft possible, (12) can be utilized as an assault weapon.

Early last June, Col. George Herring, Commanding Officer of HMX-1, arranged for me [C. R. Wood, Jr.] to fly to M.C.A.S., Quantico, Va., for familiarization with Marine helicopter transport flight operations. Major Mitchel in the Sikorsky HO4S-1 flew me into the heavily wooded helicopter practice area and performed feats that I had not thought possible. We landed in and took-off (sideward, forward, and backward) from areas only a few feet larger than the diameter of the rotor blades and, in some instances, made jump take-offs. We landed on the sides of hills; we hovered with the wheels of one side only, touching to simulate actual combat operations. The flight demonstrated to me the necessity for twin-engined rotary-wing aircraft capable of flying on one engine.

C. R. Wood, Jr.
A.H.S. Vice-President—
Midwestern Section

Members on the Move

(*Continued from page 58*)

René M. Bloch (M.), Head of all Research and Development for the French Naval Air Force, with Service Technique Aéronautique, 4, avenue de la Port d'Issy, Paris (15°), France. Formerly, Technical and Management Control Engineer, Overhaul and Repair Yards, French Naval Air Force, Toulon, France.

Harris L. Bode (T.M.), Engineering Instructor, Cal-Aero Technical Institute. Formerly, Tool Engineer "A," Boeing Airplane Company.

Tim S. Chiu (T.M.), Associate Engineer, Trans World Airlines, Inc. Formerly, Structural Detail Designer, Special Structural Section, Sverdrup & Parcel, Inc.

M. E. Davidson (T.M.), Supervisor, Engineering, Land-Air, Inc. Formerly, Flight and Service Engineer, Ryan Aeronautical Company.

Raymond J. Flynn (M.), Special Design Engineer, Foster Wheeler Corporation. Formerly, Design Analytical Engineer, Fairchild Engine Division, Fairchild Engine and Airplane Corporation.

Herbert R. Gleyre (T.M.), now Aerophysics Engineer, Fort Worth Division, Consolidated Vultee Aircraft Corporation.

Lieutenant Colonel Leon S. Jablecki, U.S.A.F., (M.), Aeronautical Engineer, U.S.A.F. Institute of Technology, Wright-Patterson Air Force Base, Ohio, Assigned to the Swiss Federal Institute of Technology, Zurich, Switzerland.

George K. Jerahian (T.M.), now Engineering Draftsman, North American Aviation, Inc.

Berthold A. Lindner (M.), Chief Engineer, Arlington (Tex.) Plant, Buick-Oldsmobile-Pontiac Assembly Division, General Motors Corporation. Formerly, Representative Assigned to Kaiser-Frazier Corporation, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation.

Captain Albert J. McDonald, U.S.A.F. (T.M.), Deputy Chief, Projects Branch, 6541st Missile Test Wing, Joint Long Range Proving Ground, Patrick Air Force Base, Fla. Formerly, Graduate Student in Aeronautical Engineering, University of Michigan.

Florren W. Mielke (T.M.), Design Engineer, Fort Worth Division, Consolidated Vultee Aircraft Corporation. Formerly, Draftsman, Allis-Chalmers Manufacturing Company.

Gerard E. Nistal (T.M.), now Advertising Manager, Government and Industrial Division, Philco Corporation.

Theodore J. Nussdorfer, Jr. (M.), Research Engineer, Arthur D. Little, Inc. Formerly, Research Engineer, Lewis Flight Propulsion Laboratory, N.A.C.A.

Eric Olsen (M.), Chief Research Engineer, Aircraft Conversion Engineering Company. Formerly, Chief of Programs Unit (Staff Engineer), U.S.A.F., McClellan Air Force Base, Calif.

W. J. Poppe (T.M.), Field Engineer, Marman Products Company, Inc. Formerly, Weight Analyst "A," Douglas Aircraft Company, Inc.

Delmar G. Underwood (T.M.), Liaison Engineer, Ford Aircraft Engine Division, Ford Motor Company. Formerly, Junior Designer, Goodyear Aircraft Corporation.

James T. Van Meter (M.), Engineer in Transonic Control Project, Aeronautical Department, Massachusetts Institute of Technology. Formerly, Analytical Engineer, Research Department, United Aircraft Corporation.

Ensign Bruce Wilcox, U.S.N. (T.M.), U.S.S. Joyce, c/o Postmaster, New York, N.Y. Formerly, Graduate Student, Rensselaer Polytechnic Institute.

Corporate Member News

• **Airborne Instruments Laboratory, Inc.** . . . George C. Hansen, formerly Technical Services Supervisor, has been promoted to Director of Procurement.

• **Aluminum Company of America** . . . Frank L. Magee, Alcoa Vice-President and General Production Manager, was elected a Director of the company. At the same time Alfred M. Hunt, a member of the Board of Directors, was elected Secretary to succeed J. R. D. Huston who has retired.

• **American Airlines, Inc.** . . . The Magnetronic Reservisor, an electronic "brain" recently put into service by American in New York, is designed to keep accurate and up-to-the moment information on all available seats on American's 1,000-plus flights over a 10-day period and to reduce to seconds the time it takes to make a passenger's reservation. Any ticket or reservations agent can, in a matter of seconds, determine space available and make or cancel reservations by simple manipulation of the keys on an agent set that resembles a small adding machine. The Reservisor was developed by American Airlines and The Teleregister Corporation at a cost of about $500,000.

• **Aviation Engineering Corporation** . . . I. R. Goldsmith has been appointed Assistant to the President.

• **Beech Aircraft Corporation** . . . A new $1,300,000 building for T-36A development and production, being constructed south of the company's main Wichita plant, will add 111,000 sq.ft. of floor space to the Beech facilities and will bring the total amount of space owned or leased by the company to over 1,500,000 sq.ft. The target date of the completion of this new building has been set as January, 1953.

• **Bell Aircraft Corporation** . . . The Disabled American Veterans Plaque was presented to Bell at the recent D.A.V. convention dinner in recognition of the corporation's "outstanding record in the employment of disabled veterans." Julius

Another First for Allison

1,000,000 hours in the air for J33 Turbo-Jet engines

Allison jet engines were the first to accumulate a million hours in the air. Now Allison J33 jets *alone* have surpassed this figure. In addition, Allison J35 engines are fast approaching the million-hour mark.

Records like these are further proof that Allison leads the world in experience—where it counts most—*in the air!*

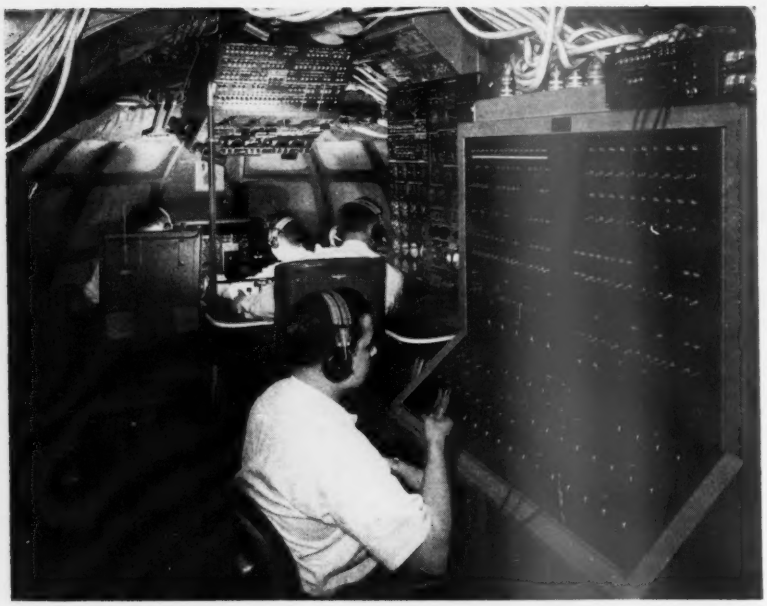
Thousands of hours on the Allison J33 are being accumulated in Lockheed Shooting Stars on tank-busting sorties behind enemy lines in Korea.

GM GENERAL MOTORS

Allison

DIVISION OF GENERAL MOTORS
INDIANAPOLIS, INDIANA

Designers and Builders of J35 and J71 Axial, J33 Centrifugal Turbo-Jet Engines, T38 and T40 Turbo-Prop Engines



C97-A SIMULATOR

Curtiss-Wright Corporation's Electronic Division recently completed an electronic simulator for the Boeing C-97A and delivered it to the U.S.A.F. early last July. This is said to be the most advanced training unit ever completed for cargo-type aircraft and represents a substantial progress in design over earlier simulators. The above picture shows the cockpit of the C-97A simulator. The pilot's head is just visible (left) over the top of his seat; the copilot is to his right, and the flight engineer is immediately behind the copilot. The flight instructor is nearest the camera.

J. Domonkos, A.M.I.A.S., Bell's Vice-President—Engineering, accepted the plaque.

• **Boeing Airplane Company** . . . The first of a new and improved type of Boeing Stratofreighter, designated KC-97F, was delivered to the U.S. Air Force for use with the Strategic Air Command. The KC-97F, the tenth model in the C-97 family, is powered with Pratt & Whitney Wasp Major R-4360-59 engines. . . . A 55,000-lb. heavy-duty Kenworth truck, powered with the Boeing Model 502 gas-turbine engine, made a test run on June 4 from Canada to Mexico. This is believed to be the world's first gas-turbine-powered highway truck. Comparing the Model 502 gas-turbine engine with present diesel truck engines of comparable output, the 502 is at least 3,000 lbs. lighter and occupies only 13 per cent of the space required by a diesel. The engine, developed by Boeing under U.S.N. sponsorship, has been service tested as the power plant for a helicopter, a Navy personnel boat, and a Navy landing craft. It is currently being manufactured on a production basis by Boeing to supply electrical power for Navy minesweepers. . . . Ralph L. Bell has been appointed Sales Manager, assuming the sales duties formerly accomplished by Frederick B. Collins, who resigned as Boeing Vice-President—Sales Manager.

• **Canadair Ltd.** . . . Roger I. Harris, formerly Deputy General Counsel for the Atomic Energy Commission, was elected Vice-President of the parent company, General Dynamics Corporation, and Assistant to the Chairman of the Board of Canadair.

• **Cessna Aircraft Company** . . . Sheldon Coleman, President, Coleman Company, Inc., was elected a Director of Cessna, replacing Will G. Price, Sr., deceased.

• **Chase Aircraft Company, Inc.** . . . Joseph H. Mendelsohn and Herbert E. Ryker have been appointed Assistant Comptroller and General Manager, respectively, of Chase.

• **The Chase National Bank of the City of New York** . . . An advertisement placed by Chase in certain New York newspapers during the last part of June told of the part that bank money plays in developing "new, faster, better aircraft."

• **Consolidated Vultee Aircraft Corporation** . . . Antenna studies on a B-36 test model at the Fort Worth Division are being conducted. The objective is to eliminate the present "clothes-line" type of antenna which stretches from the nose to the tail and in so doing produces drag. . . . As of about this coming mid-December, all B-36 production and modernization will be conducted simultaneously at the Fort Worth Division. At present, operational B-36 modernization is being accomplished at San Diego . . . . The Executive Development Plan, recently initiated by Convair for the systematic appraising, counseling, and training of executives for more important positions in the general office and manufacturing divisions, is made up of five major phases. These are: (1) an inventory of executive personnel, (2) an analysis of executive positions, (3) a comparison of executive personnel and positions, (4) the preparation for training candidates, and (5) the actual training of candidates of executive positions.

• **Curtiss-Wright Corporation** . . . The Wright Aeronautical Division has completed an agreement with The Bristol Aeroplane Company, Ltd., of England, for the development in the United States of the Bristol Olympus axial-flow turbojet engine. The Olympus, described as "the most powerful in the world," was designed to obtain a high-compression ratio through the use of two axial compressors—and turbines—in series. Some of the Olympus' details are: diameter, 40 in.; length (intake flange to exhaust flange), 124 in.; weight, 3,520 lbs.; maximum thrust, 9,750 lbs.; and consumption (lb./lb thrust/hour), 0.766 . . . An 8-page brochure entitled "The Wright 800 Horsepower Cyclone" is now being distributed to interested persons in the aviation industry.

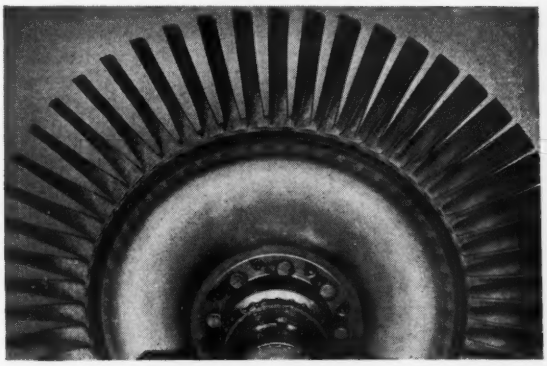
• **Douglas Aircraft Company, Inc.** . . . It has been confirmed that the Navy-Douglas 558-2 Skyrocket attained an altitude of 79,494 ft. and a speed of 1,238 m.p.h. during its flight in August, 1951, with Bill Bridgeman, Douglas Test Pilot, at the controls. The Skyrocket was launched from the mother ship, a B-29 bomber, at 35,000 ft. This bettered the record for human ascent established in 1935 by two Army balloonists who reached an altitude of 72,394 ft.

• **Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation** . . . A roadable cargo pack for the XC-120, a rough-field landing gear, a new three-piece engine cowl, and "beaver-tail" doors for heavy cargo drops have been developed recently by Fairchild. The roadable cargo pack is a detachable air-borne cargo pod that can be hauled along the highway like a conventional freight trailer. The new rough-field gear features lever-type suspension and extremely long oleo-strut travel; provisions have been made to install an extra set of wheels for landings in exceptionally soft or rough fields. The three-piece engine cowl has its two lower sections hinged down the center and the top section hinged so that it can fold back over the nacelle, thus permitting an improved accessibility and longer life. The "beaver-tail" door is designed to be opened and closed in flight. Its bottom section may be retracted into the upper section in flight for heavy cargo drops or for paratroop jumps; on the ground, the doors may be positioned to meet virtually any special loading situation. . . . The J-44 turbojet engine is being tested in a Douglas C-47 as an auxiliary-thrust power plant for rapid take-off. The engine was originally developed for missile use.

• **General Electric Company** . . . What is said to be the "world's largest and most powerful 'human centrifuge'" and which can reportedly accelerate from a dead stop to 173 m.p.h. in less than 7 sec. was put into operation on June 17 at the Naval Aviation Medical Acceleration Laboratory, Johnsville, Pa. The machine, built by McKiernan-Terry Corporation, is powered by a G-E 180-ton vertical direct-current motor that has a 4,000-hp. rating and can develop 16,000 hp. momentarily. Able to subject pilots to extreme gravitational conditions encountered in sonic-speed aircraft, the device is being used by the Navy to evaluate human tolerance to

The NIMONICS

high-temperature alloys that offer many useful properties.



HERE IS HOW the Nimonic "80"A blading of a J-42 turbine looks after 500 hours of test running. The blades, according to Pratt & Whitney, are in almost as good condition as they were at the start of the test.

As time passes, you'll hear the Nimonics talked about with increasing frequency.

And with good reason! The Nimonic alloys (we'll discuss two of them individually in a moment) are high-temperature alloys. Their characteristics are frequently sought by aircraft designers.

Let's consider Nimonic "75" (available in sheet only) first. Offering high resistance to oxidation and corrosion, it is particularly useful wherever a limited creep deformation can be tolerated under steady load and at high operating temperatures.

Up to now, Nimonic "75" has been used mainly for nozzle guide vanes, flame tubes and other combustion chamber components in British and American aircraft turbines. But its field, of course, is not strictly limited to these applications. Wherever inlet temperatures push above 1450° F., Nimonic "75" may well be kept in mind. It provides:

- High creep and fatigue strength
- High oxidation resistance at elevated temperatures
- A low coefficient of expansion, similar to mild steel (holds distortion to a relatively low level)

The second of these high-temperature alloys (available in bar stock only) is Nimonic "80"A. This is the standard material used for moving blades in nearly every production aircraft turbine in Great Britain. It is the material used, too, for turbine blades of Pratt & Whitney J-42 Turbo-Wasps, the jets that have flown more than 150,000 hours *without a single turbine blade failure.* The picture above shows the excellent condition of these blades after a 500-hour test run.

Essentially a forging alloy, Nimonic "80"A compares favorably with other alloys designed for long periods of high-temperature service under stress. While its superior creep resistance is largly responsible for its suitability as a blade material, its high oxidation resistance at elevated temperatures and its high fatigue strength under stress are also important.

Both of these Nimonic alloys have working qualities that greatly increase their range of usefulness to the designer. They can be machined by commonly-used methods, and with standard equipment. Their toughness and capacity for work-hardening, however, call for careful tool placement, fairly slow cutting speeds and generous use of lubricant.

Welding is readily accomplished by any of these methods: oxy-acetylene, inert gas arc, metallic arc, flash, spot, stitch, seam or butt. Detailed information on procedures is available, and Inco's Technical Service Section will be glad to furnish it upon request.

In fact, when you need help with any metal problem involving high temperatures, call on Technical Service. There's no charge, no obligation.

One more point, and we'll be through. The Nimonics – like other Nickel Alloys – are on extended delivery because of defense needs. So it is important to include NPA rating and complete end-use information with all orders.

Approximate Composition

	NIMONIC "75"	NIMONIC "80" A
Carbon	0.08 – 0.15%*	0.10 max.
Manganese	max. 1.00	1.00 max.
Sulfur	max. 0.015*	0.015 max.
Silicon	0.30 – 0.80	1.00 max.
Chromium	19.00 – 21.00	19.00 – 22.00
Titanium	0.25 – 0.50	2.00 – 2.75
Iron	max. 2.00	2.00 max.
Copper	max. 0.50	0.50 max.
Aluminum	max. 0.40	0.90 – 1.50
Nickel	Remainder	Remainder

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MONEL® • "R"® MONEL • "K"® MONEL "KR"® MONEL • "S"® MONEL • NICKEL • LOW CARBON NICKEL • DURANICKEL® • INCONEL® INCONEL "X"® • INCOLOY • NIMONICS

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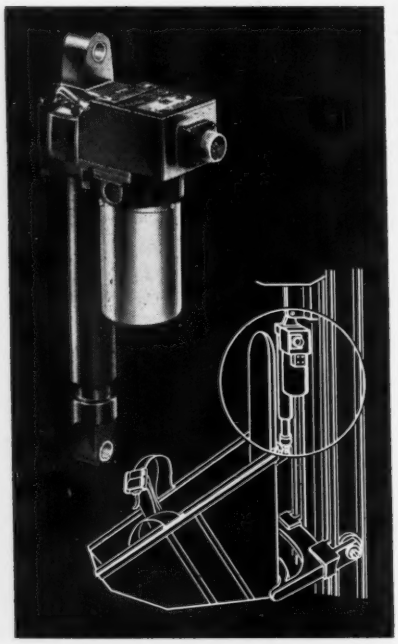

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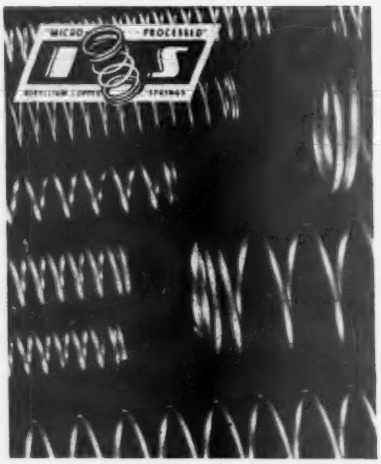
acceleration and to study the physiological systems limiting the tolerance. Special electronic controls in the machine were also furnished by G-E. . . . The new $6,000,000 electronic tube plant at Anniston, Ala., was dedicated on June 12. . . . George Fouch has been appointed Manager of Subcontracting for the Aircraft Gas Turbine Division.

• **Goodyear Aircraft Corporation of The Goodyear Tire & Rubber Company** . . . The helium-filled ZPN-1, the largest nonrigid airship yet built, was delivered to the U.S. Navy on June 17, after having been flown by a civilian crew from Akron, Ohio, to the Naval Air Station, Lakehurst, N.J. The blimp, designed for antisubmarine warfare, measures 324 ft. in length and 95 ft. in height. The gas envelope of the ZPN-1 has a helium capacity of 875,000 cu.ft. and is made of a tough rubberized nylon fabric. The engines are so located that they can be maintained and repaired while the ship is in flight. The ZPN-1 can do approximately 80 m.p.h.

• **The M. W. Kellogg Company** . . . New production facilities, representing an initial expenditure of about $1,000,000, are now under construction at Jersey City, N.J., and are expected to go into operation before the end of this year. This new plant will enable Kellogg to expand its military and industrial production of Kel-F, the fluorocarbon-type plastic with "extraordinary resistance to heat, moisture, and chemical action." According to company claims, Kel-F is a thermoplastic material that is chemically inert, has a high electrical resistance, exhibits zero water absorption, has a wide temperature range, and can be molded and machined. It has been used in transformer terminals, valve diaphragms, drum and tank liners, electronic caps, antenna bases, etc.

• **Lear, Incorporated** . . . Sales and service operations for the Pacific coast have been expanded with activities for all divisions being handled directly by company representatives. Headquarters for the California territory will be 11916 West Pico Blvd., Los Angeles, while that for the Seattle territory will be at Box 60, Terminal Building, Boeing Field, Seattle, Wash.

• **Lockheed Aircraft Corporation** . . . A new production aircraft, the Lockheed F-94C Starfire, has been announced by Lockheed and the U.S. Air Force. The F-94C, an all-weather jet interceptor designed for the air defense of the United States, is armed with 24 air-to-air 2.75-in. rockets that fire from a ring of tubes around the nose. It can also carry additional rockets in new-type armament pods on the wings. The aircraft is powered with the new Pratt & Whitney J-48-P-5 jet engine that produces a 6,250 thrust without afterburner . . . The first Super Constellations powered with Wright compound engines will be delivered this year to the U.S. Navy and will be known as the R7V-1. The maiden flight of this plane with the compound engines was scheduled for last July. Depending upon the need, this aircraft can be converted into (1) a 106-passenger transport, (2) a 73-litter hospital plane, or (3) a 17½-ton-pay-load air freighter. The first civilian delivery of the Super Constellations is scheduled to go to K.L.M. Royal Dutch Airlines early in



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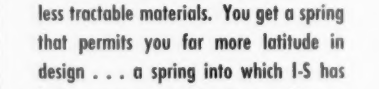

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1953. Subsequent deliveries to civilian companies go first to Air France and then to Eastern Air Lines.

• **Marquardt Aircraft Company** . . . Dr. Clark B. Millikan, H.F.I.A.S., Director, Guggenheim Aeronautical Laboratory, California Institute of Technology, and Clarence E. Unterberg, of the New York financial firm of C. E. Unterberg & Company, were elected to Marquardt's Board of Directors.

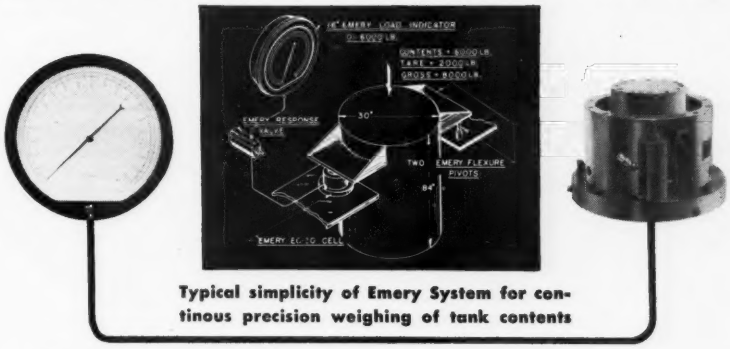
• **McDonnell Aircraft Corporation** . . . Joseph H. Cennater, who has been serving as McDonnell's Assistant Treasurer, was elected Treasurer of the Company. He succeeds Philip M. Cozad who resigned as Treasurer and Director.

• **Minneapolis-Honeywell Regulator Company** . . . In a move to expand research and development work in the field of hydraulic actuators, the Aeronautical Division has established a new hydraulics testing laboratory. One of the features of this new facility, which includes the latest devices for producing a wide range of test pressures, is the convenience of environmental testing made possible by a portable hydraulics test bench that can be wheeled into the plant's high-low temperature chambers, altitude chamber, vibration room, and other all-condition testing facilities. . . . A regional office has been established in Toronto, Ontario, Canada, to provide improved service engineering for Canada's aircraft industry.

• **North American Aviation, Inc.** . . . the XFJ-2 Fury was accepted early last June by the Navy for carrier tests after the company had conducted carrier suitability tests at the Naval Ordnance Test Station, Inyokern, Calif.

• **Northrop Aircraft, Inc.** . . . Arrangements have been concluded whereby Northrop acquires 100 per cent of the stock of Radioplane Company, of Van Nuys, Calif. Radioplane will continue its production of target aircraft, as well as its research and development work, as a new division of Northrop. The transaction is, of course, subject to approval by Governmental agencies and the stock exchanges of the steps agreed upon by the two companies. Whitley C. Collins, co-founder and President of Radioplane, will continue as its president and has been named to Northrop's Board of Directors. William Larrabee will continue as Vice-President and General Manager of Radioplane; Ferris M. Smith, as Vice-President in charge of military relations; and Rollins M. Russell, as Vice-President in charge of engineering. . . . The F-89 Scorpion has completed a series of static tests conducted by the Structures Test Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. Also completed are the arctic suitability tests in which both operation and maintenance tests were run. . . . The Allison J-35-A-33 jet engine is being installed in the Northrop F-89C Scorpion. The radar-equipped F-89C with its crew of two can fly at altitudes up to 45,000 ft. It is armed with six 20-mm. cannon mounted in the nose. . . . A "windless wind tunnel" has been developed by Northrop test engineers which, through the use of an electronic analog computer, projects a life-sized hydraulic mock-up of

LET EMERY SOLVE YOUR WEIGHING PROBLEM



Typical simplicity of Emery System for continous precision weighing of tank contents

HERE'S WHY . . . Emery System *completely self-contained* • *Fast response* to load changes (less than 1/2 second) • *Accuracy* within 1/10 of 1% of range • Less than *0.005-inch deflection* under full load • *No maintenance* required.

THE PROBLEM . . . Determine accurately weight of liquids frequently added and withdrawn from 6000-pound capacity tank mounted mostly below floor level.

THE SOLUTION . . . Three-point tank mounting on two Emery Flexure Pivots and one Emery EC-30 Load Cell. The dial of the 16-inch direct-reading Emery Load Indicator is calibrated to indicate precise net content of tank.

P. S. . . . Emery Response valve between load cell and indicator eliminates hydraulic surge . . . permits use of recorder or controller in addition to indicator in any Emery installation, at any distance.

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LOW COST . . . Emery Force Measurement Systems are lowest in initial cost, operation cost, and require no maintenance.

WIDE RANGE . . . Stock sizes available for precision measurement of one to 100,000 lb. Special sizes, up to 10,000,000 lb.

CONTROLLED RESPONSE . . . Simple valve adjustment (even after installation) can delay inherently fast response to give readings in load fluctuation or provide steady readings of mean value of vibrating loads.

PNEUMATIC LOAD CELLS . . . with typical Emery precision and simplicity are also available for smaller loads.

WHY NOT . . . let Emery Engineers help you with your force measurement problem? Fill out the coupon TODAY, whether you need information on Weighing . . . Brake Testing . . . Torque and Torsion Measurements . . . Cable, Chain, and Rope Testing . . . Strength of Materials and Structures . . . Jet Engine Thrust . . . Towing and Traction Tests . . . or some unusual problem of your own.

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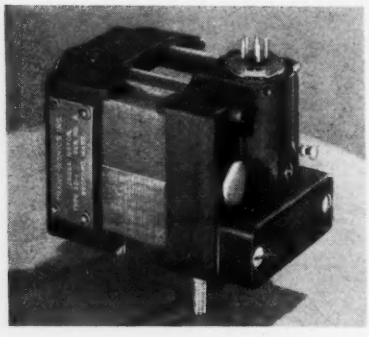

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Type 35

TORQUE MOTOR

DESIGNED to move a valve such as the control valve in hydraulic servo-mechanisms . . .

- FAST RESPONSE
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- BALANCED AGAINST ACCELERATION EFFECTS
- IN PRODUCTION
- FULLY PROVED BY EXTENSIVE FIELD USE

Brief Specifications:
STROKE: ± 0.004"
SENSITIVITY:
A—Deflection: 0.001" per milliampere of signal current
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NATURAL FREQUENCY: > 400 cps
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Write for Bulletin 35

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Transducers: Acceleration - Pressure - Temperature
Electro-Hydraulic Amplifiers
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an F-89 through all the maneuvers of a high-speed high-altitude test flight. This is accomplished by connecting together a mock-up of the full-power control system of an F-89 and an electronic computer to provide preliminary information on flight performance.

• **The Parker Appliance Company** . . . The new Parker catalog 516OA1, issued in May, 1952, describes and gives complete data and dimensions for precision O-rings molded of Parkone compounds for extreme temperature resistance. Parkone O-rings, the company says, combine suitable mechanical characteristics with resistance to ambient temperatures in the −100° to +500° F. range and are also useful in static sealing applications involving resistance to oxidation, to the solvent action of high aniline oils and hydraulic fluids, or to rapid aging.

• **Piasecki Helicopter Corporation** . . . Hamilton W. Lord has been named Controller for the corporation.

• **Republic Aviation Corporation** . . . Lowery L. Brabham was elected a Vice-President of the corporation. Mr. Brabham, who was formerly Sales Manager, will continue the direction of sales activities.

• **Seaboard & Western Airlines, Inc.** . . . A Douglas DC-4 has been purchased from Braathens South-American and Far East Airtransport, of Norway. This makes the ninth of this type for Seaboard & Western.

• **Solar Aircraft Company** . . . The first British license for the use of Solar's process for producing complex sheet-metal shapes has been issued to Rolls-Royce Limited, of Derby, England. This process, known as Sol-A-Die, is particularly applicable to the forming of stainless steels used in aircraft engines. . . . A 24-page brochure has been put out by Solar entitled "The Solaramic Process, A New Means of Conserving Strategic Materials and Extending Metal Life at High Temperatures." It is available without charge from Solar's Research Products Division.

• **Sperry Gyroscope Company, Division of The Sperry Corporation** . . . W. L. Barrow, Sperry's Chief Engineer, has been named Vice-President and Chief Engineer of the company.

• **Trans World Airlines, Inc.** . . . The company has announced that all of its executive, staff, and departmental offices maintained in New York City will be consolidated in the new office building now under construction on the old Ritz Carlton Hotel site at 380 Madison Ave., New York. This 25-story building is expected to be completed in the spring of 1953, at which time T.W.A. will occupy on a 15-year lease about 30,000 sq.ft. of office space on the fifteenth and sixteenth floors. The departments to be moved into the new office space include the System Sales Department now at 60 E. 42nd St.; the Atlantic Regional Sales Offices currently at 80 E. 42nd St.; and the Executive Offices, Public Relations, Properties, Government Affairs, and Customer Relations now at 630 Fifth Ave. . . . The Traffic and Sales Department has been redesignated the "Sales Department." Its functions remain the same and are under the adminis-

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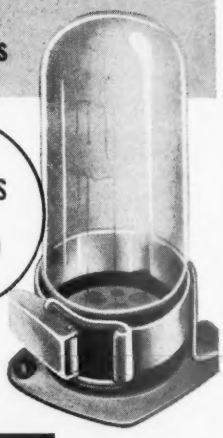

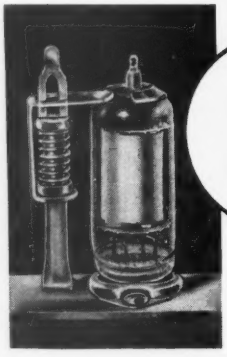

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BIRTCHER TUBE CLAMPS can be used in the most confined spaces of any compact electronic device. Added stray capacity is kept at a minimum. Weight of tube clamp is negligible.

Millions of Birtcher Tube Clamps are in use in all parts of the world. They're recommended for all types of tubes: glass or metal—chassis or sub-chassis mounted.

THERE'S A BIRTCHER TUBE CLAMP FOR EVERY STANDARD AND MINIATURE TUBE!

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tration of E. O. Cocke, Vice-President—Sales.

• **Union Carbide and Carbon Corporation** . . . Dr. Harry Bell McClure, Vice-President of Carbide and Carbon Chemicals Company, a Division of Union Carbide and Carbon Corporation, was elected the 1952–1953 Honorary Chairman of the American Section of the Society of Chemical Industry.

• **United Air Lines, Inc.** . . . A Department of Safety to be concerned with the "overall company problems of safety" has been established. C. M. Christenson, who has been a U.A.L. pilot, heads the department and will report directly to Otis E. Kline, Executive Vice-President.

• **United Air Lines and Curtiss-Wright Corporation** . . . United has placed orders with Curtiss-Wright for a total of 140 Turbo Compound engines. United is planning to equip a new fleet of Douglas DC-7 transports.

• **United Aircraft Corporation** . . .William R. Robbins, Controller and Chief Financial Officer, and Erle Martin, F.I.A.S., General Manager of Hamilton Standard Division, have been elected Vice-Presidents of United Aircraft.

• **Vickers, Inc.** . . . The company will sponsor the second Transport Aircraft Hydraulic Conference on October 28–29, 1952, at the Park Sheraton Hotel, Detroit. William E. Spearman, Assistant Manager of Service Engineering, American Airlines, Inc., will act as the meeting's General Chairman.

• **Westinghouse Electric Corporation** . . . According to a company release, "the first automatic pilot with unlimited maneuverability" was installed in the Lockheed F-94C Starfire, now being produced for the U.S.A.F. This autopilot is described as utilizing three "non-tumbling" gyroscopes that are locked to the plane. It is said to be suitable not only for military aircraft but for large and small commercial planes. Radio-controlled, it can also serve to direct the flight of guided missiles and pilotless aircraft. Developed by Westinghouse in cooperation with Air Materiel Command's Armament Laboratory, Control Equipment Branch, it is being manufactured by Westinghouse's Air-Arm Division. . . . The Special Miniature Lamp Department of Westinghouse's Lamp Division has moved from Bloomfield, N.J., to Richmond, Ky.

I.A.S. Sections

Cleveland-Akron Section

Harrison C. Chandler, Jr., *Secretary*

"Current Trends in Aviation Medicine" was the topic discussed by Dr. Clayton S. White at the final meeting of the I.A.S. Cleveland-Akron Section, held on the evening of May 20. Dr. White is the Director of Research, Lovelace Foundation, Albuquerque, N.M.

Setting the precedent in the activities of this section, this was a joint meeting

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. . . and anything less than the utmost in dependability can result in disaster. The electronic components that carry the pulse of ground-to-air communications and G.C.A.* must function perfectly at all times. In addition, the connectors that carry the power from the aircraft's generators to the electronic instruments and to the motors which operate the control surfaces etc., must not fail!
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THE CONSTELLATION & SUPER CONSTELLATION

On every continent of the world leading airlines fly the famous Constellation. Today more people fly over more oceans and continents on the Constellations of these great airlines than on *any other modern airplane.* It is also the leader on the most traveled route, the North Atlantic. This successful operation by international airlines established the Constellation's record for dependable performance—leading to the development of the new Super Constellation, today's finest transport airplane. No other modern airliner has been reordered so often. Whenever you travel, insist on the dependable Constellation service of these airline leaders.* If there is no local office in your city, see your travel agent.

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SUPER CONSTELLATIONS MAKE MONEY FOR AIRLINES

KLM Royal Dutch Airlines have just placed their *third* successive order for Super Constellations. Here is powerful indication of a famous airline's opinion of this larger, more luxurious successor to the experienced Constellation. KLM plans to put their Super Constellations into service on the heavily competitive North Atlantic route, where long range and superior performance are paramount.

Announced simultaneously was a new order for Super Constellations placed by Linea Aeropostal Venezolana. LAV also made their selection after careful consideration of the finest competitive equipment. This choice is backed by their long previous experience with dependable Constellations.

Why have a total of 12 world airlines ordered Super Constellations, bringing Lockheed's Constellation production line to the greatest peak in its continuous 8 year history?

The answer is very simple—*it's because this great airplane has been proved to make money.*

RECORD REORDERS

Here are some of the basic reasons why the Constellation has been reordered more often than any other modern airliner:

1. It offers longer life and therefore greater profit on the investment—because it is designed to grow further. (The Super Constellation now flies 133,000 pounds at 350 m.p.h., and when more powerful engines are available it will carry 150,000 pounds at 425 m.p.h.).

2. The Super Constellation is versatile and can be easily changed in a few hours to carry as many as 94 passengers. Thus it can be used for many purposes on many routes to meet changing competitive conditions.

3. Airlines like its low operating cost. It is practical and reliable, and it makes money.

4. It has longer range than any other commercial airplane.

5. It can match in speed the competitive schedules of any airliner.

6. Operators like it because travelers like it—for dependability, luxury and speed.

Thus the Constellation and now the Super Constellation are currently playing a vital role in profitable airline operation, at the same time giving assurance of future profit because of the built-in "growth factor" not found in any other airplane.

held with the Cleveland Academy of Medicine. The location was the Medical Library Building Auditorium on the campus of Western Reserve University.

The physiological problems encountered during flight operations at very high altitudes, possible with jet- and rocket-powered aircraft, are much more serious than most people realize, Dr. White emphasized. These problems include a rarified atmosphere of low oxygen content, cosmic radiation, poisonous concentrations of ozone, X-rays, and ultraviolet radiations from the sun.

Data presented by Dr. White showed that cosmic radiation reaches a very high level of energy at about 62,000 ft. altitude at certain latitudes. The amount of radiation varies with latitude and with time of the year. Further data are required in order to have a detailed picture of the danger zones of altitude, season, and latitude for cosmic radiation.

Another limiting factor regarding high-altitude flight is that of cabin pressurization. Dr. White presented data prepared by one of the major aircraft manufacturers which indicate that 70,000 ft. is the practical upper limit of flight from this standpoint. At that altitude, a pressure ratio of 11 is required in order to maintain a cabin pressure equivalent to about 8,000 ft.

Concentration of ozone in the atmosphere has been found to reach a peak between 60,000 and 70,000 ft. altitude. As in the case of cosmic radiation, peak ozone concentrations vary somewhat with season and with latitude. Ozone is not readily discernable to the airplane pilot. At present, there exists a need for an accurate device to measure ozone concentrations in airplane cabins. The maximum allowable concentration of ozone for chronic exposure is 1.0 parts in a million parts of air, as compared to 100 parts for carbon monoxide and far greater percentages for other toxic substances.

Concerning solar X-rays and also ultraviolet radiation from the sun, there is little information at present on man's tolerance to such exposure at high altitude. Data on these problems must be obtained soon, Dr. White said, in view of the increasing trend toward high-altitude flight.

Dr. White also stressed the importance of obtaining dependable information on temperatures aloft, to be used as a basis for design of airplane cooling systems and heating systems. He pointed out that published data have been found to be in great error. Engineering problems in this field which must be solved include aerodynamic heating and determination of heat transfer in a near vacuum.

Attendance at the meeting was about 120. Prior to the joint meeting with the Cleveland Academy of Medicine, the I.A.S. members held a dinner meeting at Tomlinson Hall, located on the adjoining Case Institute of Technology campus. The purposes of this meeting were to elect officers for the coming year and to discuss the program of meeting topics which is being considered for the 1952-1953 year.

The following officers were elected by the section to serve during the coming year: Chairman, Lewis A. Rodert; Vice-Chairman—Cleveland, and Program Chairman, E. C. Sulzman; Vice-Chairman—Akron, H. C. Chandler, Jr.; Secretary-Treasurer, Ray E. Bolz; and Chairman of Membership and Attendance Committee, Ralph Eschborn.

Our retiring Chairman, E. W. (Pop) Cleveland, was given a rising vote of thanks for the splendid record of achievement which the Cleveland-Akron Section has made during the past year under his leadership. Attendance at meetings has far eclipsed that of all previous years, and the program of meetings has been excellent, thus generating greatly increased interest by the members and others in the Cleveland-Akron area who are interested in aviation.

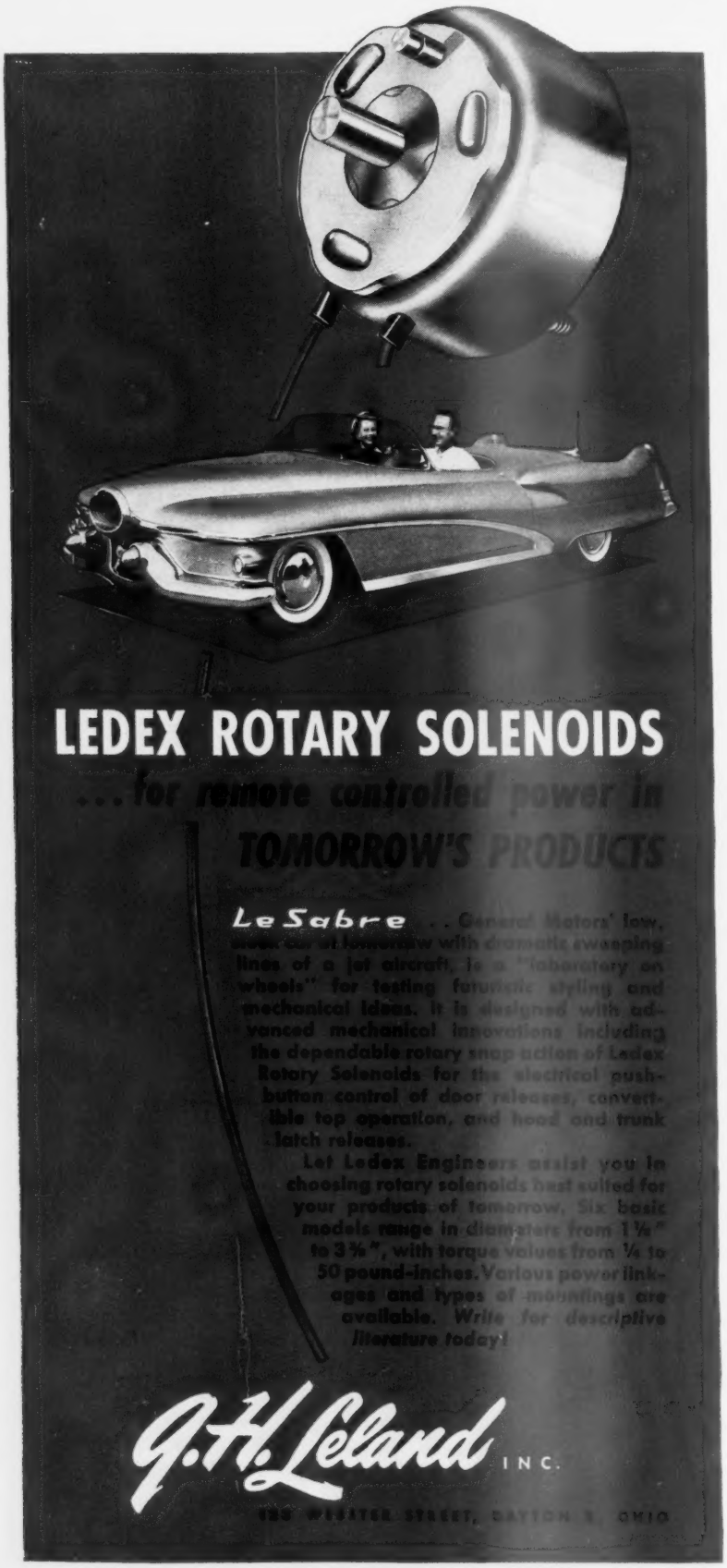
Hampton Roads Section

Albert L. Braslow, *Recording Secretary*

Robert Sanders, President, Sanders Aviation, distributors of the Ercoupe, addressed approximately 75 members and guests of the Hampton Roads Section on last March 19. Special guests at the meeting were members of the Icarian Flying Club of the Patrick Henry Airport. Mr. Sanders was active in the early development and flight testing of the Ercoupe two-control airplane. The subject of his talk was "Private Flying, What It Is and What It Isn't, and Why."

Mr. Sanders pointed out that the term "private flying" used in his talk applied to the type of flying wherein the airplane is piloted by the owner for either pleasure or business. The private airplane is used, for example, for vacation transportation, sports transportation, business transportation, local pleasure flying, or industrial purposes, such as dusting, instruction, sight-seeing, taxi service, and photography.

In reviewing the growth of private aviation since 1941, Mr. Sanders mentioned that in that year, 7,600 private airplanes were delivered to bring the total number in existence to 25,000. The total number of licensed pilots at that time was 100,000. In 1946, the number of private airplanes had increased to 85,000 and the number of pilots to 400,000, mainly as a result of the war. Expectations for the future of private flying were bright in 1946, and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predictions were made that 500,000 airplanes would be in use by 1950. As a result of these predictions, construction of private planes was begun in 1947 at the same rate of construction as during 1946, when 34,000 planes were built. Actually, only 15,000 private planes were delivered during 1947. The number of private planes in this country reached a peak in 1948 and has decreased since then. At the present time, only 88,000 private planes are in use, although there are now 600,000 pilots.

Mr. Sanders devoted the main part of his talk to a discussion of the reasons why he believes the bright predictions of 1946 regarding private aviation have not materialized. In brief, these reasons can be reviewed as follows: (1) the private airplane is not as dependable as the automobile, mainly because of the limitations imposed upon it as a result of adverse weather; (2) the cost of the airplane and the cost of the operation are both high; (3) the safety record of private aviation is not too good, although the publicity is a great deal worse than the accidents; (4) the private airplane still lacks sufficient speed, mainly because of terminal delays such as the time required in traveling to and from too few available airports; (5) there is a lack of social prestige in the ownership of a private airplane that is not evidenced in the ownership of other types of transportation; (6) too much overselling of private airplanes has resulted in considerable disappointment to many people after learning to fly.

In order to increase the interest in private flying, Mr. Sanders stated that it would be necessary to improve the dependability, safety, and speed of the private airplane and also to reduce its cost. He also mentioned that the helicopter or the roadable airplane may offer the solution to most of the previously mentioned shortcomings of private flying as it exists today.

Mr. Sanders concluded his talk with an entertaining sales movie that was a perfect example of the overselling techniques used only a short time ago. An enthusiastic discussion of private flying followed which clearly indicated the interest with which Mr. Sanders' talk was received.

Montreal Section

H. V. Braceland, *Secretary*

Approximately 130 members and guests were present in the mess of the 401 Fighter Squadron, R.C.A.F., to hear Stanley W. Smith, Project Engineer—Research Aircraft, Bell Aircraft Corporation, speak on the X-1 and the X-2.

E. Schaefer opened the meeting by a short discussion of the section's activi-

ties and then introduced the guest speaker by stating that Mr. Smith was Project Engineer on the Bell X-1, the first aircraft to exceed the speed of sound, and that Mr. Smith was playing an important part in the development of the X-2.

Mr. Smith introduced the subject by detailing the general contours of the X-1, mentioning the development work required on both the X-1 and X-2. It was certainly interesting to discover the problems associated with the design of high-speed aircraft.

It was stated that in order to obviate or reduce drag and buffeting of the tail section from the wing wake, an extremely thin wing was required. For similar reasons and for control, even thinner sections were required for the tail plane.

The fuselage was designed with simplicity as the theme. Space was a premium, since such large quantities of fuel would be required. Large diametric "pipes," approximately 3 in., were necessary to allow 1,600 gal. of fuel to be fed to the power unit in 3 min. This required considerable design and development work. Valves created a new problem in that surge had to be prevented by controlling the rates of opening and closing. Associated with the rapid flows in the fuel system, a critical situation arose with regard to the center of gravity. The maximum take-off weight was approximately 13,000 lbs., 8,000 lbs. of which was fuel. This fuel was sufficient for only 3 min.

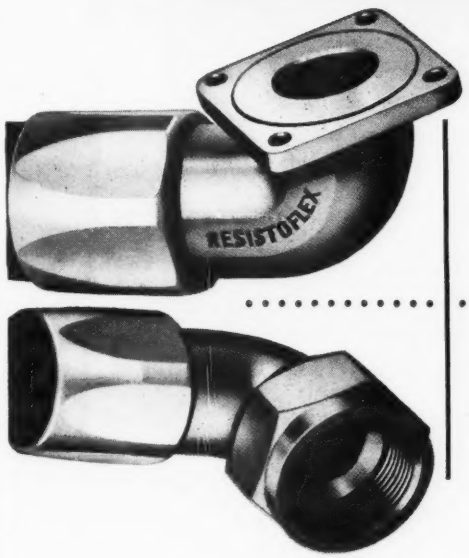
Considerable high-temperature structure problems were encountered and successfully solved. The use of liquid oxygen at −300°F., with a skin temperature of 700°F. and air temperatures of 1,100° F., created differential temperature strains and "creep" even to the yielding of the material.

The pilot's comfort had to be considered. Consequently, the windshield was fully tempered plate glass treated green to filter infrared rays to prevent sunburn.

No refrigeration was required because of the short durations of flight; the insulation designed into the aircraft was sufficient. Pressurization was supplied from a compressed-air bottle. Fogging of the windows was prevented by dry nitrogen blast.

An emergency bail-out system was designed for altitudes of 100,000 ft. and 20-g forces. The method used was a jettisonable capsule that would maintain pressurization until an altitude was reached where the seat would be ejected from the capsule. From a lower altitude, the pilot could release his chute.

Some problems were presented with regard to the use and handling of liquid oxygen. For example, feed pipe-line experiences showed considerable shrink-



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age due to the extremely low temperature; seals were made out of treated leather, etc.

In closing, Mr. Smith discussed some of the problems associated with rocket motors and the complications encountered during installation.

Two excellent films were shown depicting the operation of the X-1 aircraft on the ground and its launching from a mother ship.

A lively discussion period followed the films, after which Mr. Higgins thanked the speaker and Mr. Schaefer adjourned the meeting.

Student Branches

Academy of Aeronautics

Two films were shown at the May 21 meeting entitled *Structures* and *Holiday in Miami*. Chairman Nickolas Kruger presided.

Georgia Institute of Technology

At the May 30 meeting, the following awards were presented: the Outstanding Service Award to George O. Kelbert; the Technical Award for the highest grades in aeronautical engineering subjects to Wesley M. Mann, Jr.; and the award for the Best Seminar Paper of the year to Robert Whittaker.

An election of officers was held at the previous meeting. Those elected were: Chairman, Jack McAllister; Vice-Chairman, Sid Powers; Secretary, Bob Albritton; and Treasurer, Bob Stancil.

University of Maryland

The following students were elected to office for The coming year at the May 14 meeting: Chairman, Leonard Tinnanoff; Vice-Chairman, Robert Hess; and Secretary-Treasurer, Ralph Vendemia. Chairman Allen A. Bowers presided; 24 students were present.

The Pennsylvania State College

Frank A. Leader, *Secretary*

To close out its activities for the 1952 semester, The Pennsylvania State College Student Branch held its final meeting on May 14. About 30 members witnessed the turning over of the "joy stick," traditional symbol of leadership for the local branch, to Max Schuster by the retiring Chairman, George Page.

After a few remarks by Mr. Schuster, the final two I.A.S. Student Paper contestants presented their talks. The first, by Sam Porter, was entitled "Combustion Chamber Losses in Jet Engines." It was of a technical nature, giving formulas for finding the different losses and employed a combustion-

chamber pressure-loss chart from which can, jet, and angular losses could be read. Jim Scherer's "Jet Transports" was the closing talk. In it, he expounded on the design and application of today's jet transports and the problems involved. One interesting note was that the United States is definitely behind other countries in the use of jets for commercial use.

Polytechnic Institute of Brooklyn

The elected officers for 1952-1953 are: Chairman, Fritz Blomback; Vice-Chairman, George Myers; Treasurer, Robert Cresci; Recording Secretary, Anthony Casaccio; and Corresponding Secretary, Roger Couture.

The Ohio State University

Sterling Starr, *Secretary*

The May 7th meeting of The Ohio State University Student Branch was called to order by Chairman Richard G. Docken with 13 members present.

The speaker of the evening was Lieutenant Colonel Calvin G. Dietrich, U.S.A.F., of the Air Technical Intelligence Center, Wright-Patterson Air Force Base, Dayton, Ohio. The title of his talk was "Air Technical Intelligence."

Colonel Dietrich in his talk gave a history of technology. He explained the role of technological surprises in warfare and gave examples of military dominance due to technological advantages. He mapped the role of the Air Technical Intelligence Center, explaining its make-up and how it functions. After the talk, he answered questions.

During the business meeting, plans were completed for participation of the Branch in the biennial Engineers' Day held on May 16th. The Branch built a float for the float parade and sponsored the departmental exhibit.

▸ The May 21st meeting was called to order by Chairman Richard G. Docken with 15 members present.

The speaker of the evening was Mr. Mayne, affiliated with Goodyear Aerophysics Laboratory.

Mr. Mayne in his talk gave a literal description of the guided missile as a complete high-speed airplane with the added talent of being a "thinking" machine. He explained the development of the guided missile as a natural evolution of the present-day complex aircraft in which the pilot acts as an equipment monitor. He emphasized the complexity of the development program due to the fact that guided missiles can only be tried once; then a completely new one is built incorporating needed improvements or variations.

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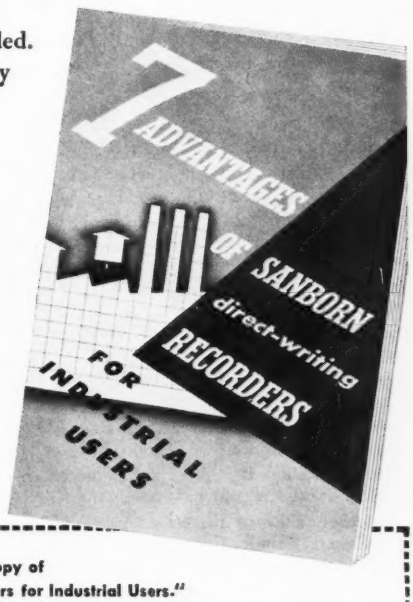

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Mr. Mayne also expounded some of the general philosophy of weapon design, demonstrating the reasons it is necessary to keep developing new ideas.

University of Oklahoma

Chairman Melvin E. Dell called the May 21 meeting to order with 10 students present. An election of officers for the coming year took place with the following results: Chairman, Lawrence Fred Smith, and Vice-Chairman, Secretary, and Treasurer, Robert D. Meyer.

Syracuse University

The election of officers for the 1952-1953 academic year took place at the April 24 meeting with the following results: Chairman, Robert Mack; Vice-Chairman, Fred Boenig; Secretary, William Kelley; and Treasurer, David Birdseye. Chairman Spencer Weller presided.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Steinhoff, Ernst A., Ph.D. (Applied Physics), Scientific Advisor for Guided Missiles, Dept. of the Air Force, Holloman A.F.B.

Transferred to Associate Fellow Grade

Sepulveda, Luis A., M.S. in M.E., Chief Engineer & Aero. Adviser, International Industrial Cooperative, I.I.C.

Elected to MEMBER Grade

Bolton, Henry E., Sr. Designer, Republic Aviation Corp.

Dell'Amico, Fred, B.Sc. in M.E., Research Mech. Engr., Cornell Aero. Lab., Inc.

Feicht, Edward R., M.S. in Ae.E., Major, U.S.A.F. Exchange Officer, assigned to the Royal Aircraft Establishment & Ministry of Supply (London), U.S.A.F.

Granger, John V. N., Ph.D. in Applied Physics, Head, Aircraft Radiation Systems Lab. & Asst. Chairman, Engrg. Dept., Stanford Research Institute.

Hagedorn, Alfred A., B.M..E, E.E., Member of the Technical Staff, Hughes Aircraft Co.

Hoblit, Fred, M.S.E., Struct. Engr., Lockheed Aircraft Corp.

Johnson, Francis B., Asst. Proj. Engr., Lockheed Aircraft Corp. (Georgia Div.).

Lanning, Robert D., Staff Engr., Power Plant, Piasecki Helicopter Corp.

Lubischer, Edward E., Exec. Airplane Pilot, General Motors Corp.

Pajak, Theodore P., B.S. in C.E., Supvr., Sandwich & Bonded Struct. Unit, The Glenn L. Martin Co.

Plum, Charles R., B.S. in M.E., Contract Admin., General Electric Co. (Cincinnati).

Richardson, Sewall F., B.S.M.E., Sect. Engr., Commercial Engrg., Aircraft Gas Turbine Div., General Electric Co. (West Lynn).

Ross, Chandler C., B.S., Mgr., Liquid Engine Div., Aerojet Engrg. Corp.

Stoolman, Leo, M.S., Research Physicist, Research & Devel. Lab., Hughes Aircraft Co.

Toomey, Herbert M., Chief, Aircraft Engrg. Branch, Civil Aeronautics Administration (New York).

Tucker, John B., B.S.M.E. (Aero.), Air Design Engr., General Electric Co. (West Lynn).

Zobel, Theodor W., Dr. Ing., Specialist, Aerodynamic Instrumentation in Components Developments, General Electric Co. (Lockland).

Transferred to MEMBER Grade

Dwinnell, James H., M.S. in Ae.E., Aerodynamicist, Boeing Airplane Co. (Seattle).

Hansen, Matt J., Engrg. Designer "B," North American Aviation, Inc. (Los Angeles).

Elected to Associate Member Grade

Trost, Robert R., Mgr., West Coast Office, Aeroproducts Div., General Motors Corp.

Elected to Technical Member Grade

Conrath, Philip R., B.S., Air Loads Engr., McDonnell Aircraft Corp.

Feldman, Alvin L., B.M.E., Thermodynamicist, Consolidated Vultee Aircraft Corp. (San Diego).

Garrett, John W., B.S., Engr. 1, ARO, Inc.

Holt, H. Robb, B.S.M.E., Jr. Engr., Engine Test Facility, ARO, Inc.

Lutts, C. Gardner, Jr., B.S., Tech. Engr., General Electric Co. (River Works).

Neely, James, B.M.E., Engr. 1, ARO, Inc.

Pile, Donald E., B.S.M.E., Engr., General Electric Co. (Lynn).

Remenyik, Carl, Dipl. Ing., Asst. Instr. in Aerodynamics, Swiss Federal Institute of Technology.

Rogers, Robert A., B.A., Aerodynamics Engr., Aeroproducts Div., General Motors Corp. (Dayton).

Saunders, Edward W., Mech. Draftsman, Dowty Equipment, Ltd. (Ajax).

Spray, Cyril F., Jr. Engr., A. V. Roe Canada, Ltd. (Malton).

Treadgold, Desmond A., Scientific Officer, Royal Aircraft Establishment, Ministry of Supply.

Watkins, Stanley, Chief Draughtsman, Dowty Equipment of Canada.

Transferred to Technical Member Grade

Ballentine, Don C., A.E., Aero. Engr. GS-5, David Taylor Model Basin.

Bidne, Charles V., B. of Ae.E., Jr. Engr., Chance Vought Aircraft Div., United Aircraft Corp.

Bligh, Joseph A., B.S. in Ae.E., Jr. Engr. "B," B-52 Liaison Group, Boeing Airplane Co. (Seattle).

Boehler, Gabriel, M. of Ae.E., Research Engr., Thieblot Aircraft Co., Inc.

Bowers, Harry M., B. of Ae.E., Aerodynamicist, Guided Missiles Group, Grumman Aircraft Engrg. Corp.

Budris, George D., B. of Ae.E., Aero. Engr., Aeronautical Radio, Inc.

Burton, Clarence A., B.S., Jr. Engr., Draftsman "B," Lockheed Aircraft Corp.

Church, Paul B., B.A.Sc., Design Engr., A. V. Roe Canada, Ltd. (Malton).

Coldewey, Edwin W., B. of Ae.E., Applied Loads Engr., Grumman Aircraft Engrg. Corp.

Cornette, Elden S., B.S., Graduate Student, Virginia Polytechnic Institute.

Davidson, Roy A., Draftsman "A," North American Aviation, Inc. (Los Angeles).

De Santo, Daniel F., B. of Ae.E., Jr. Engr., Struct. Dept., Applied Loads Sect., Grumman Aircraft Engrg. Corp.

Dewart, Lewis, B. of Ae.E., 2nd Lt., U.S.A.F., A.R.D.C., Wright-Patterson A.F.B.

Diacatos, Philip, Jr., B. of Ae.E., Engrg. Trainee, Republic Aviation Corp.

Eisenstark, Harold, B. of Ae.E., Stress Analyst "C," North American Aviation Inc. (Los Angeles).

Fishburne, Paul L., Lt. Col. & Sr. Pilot, U.S.A.F.; Engrg. Staff Officer, McClellan A.F.B.

Fitzpatrick, John, Outside Inspector, Piasecki Helicopter Corp.

Garrison, Everett W., Jr. Engr.—Liaison, Douglas Aircraft Co., Inc. (Tulsa).

Gilbert, Loran M., Jr., B. of Ae.E., Engrg. Draftsman "B," Lockheed Aircraft Corp. (Marietta).

Greenfield, William D., B.S., Ens., U.S.N.

Grottland, Berthin, B.A.Sc., Engr. in Training, A. V. Roe Canada, Ltd.

Hanson, Perry W., B.S.Ae.E., Graduate Student, Virginia Polytechnic Institute.

Hay, Carl W., Engrg. Draftsman "A," Instrument Design Group, Northrop Aircraft, Inc.

Herban, Stephen E., B.S., Test Engr., Continental Motors Corp.

Hester, Keete L., B.S., 2nd Lt., U.S.A.F.

Jenkins, George L., B.S., Mech. Engr., Hughes Aircraft Co.

Jones, Howard R., B.S., Aerodynamicist, North American Aviation, Inc. (Los Angeles).

Kemper, Richard B., B.M.E. (Aero.), 2nd Lt., U.S.A.F.; Student Officer, Pilot Training, Vance A.F.B.

Krameisen, S. Murray, B. of Ae.E., Draftsman, Grumman Aircraft Engrg. Corp.

Laundry, Wm. E., B.A.Sc., Jr. Research Engr., National Research Council (Ottawa).

Mackey, Byrne C., B.S., Flight Test Analyst, Boeing Airplane Co.

Mau, David Loy, B.S. in Ae.E., Engr.'s Asst. "A," Struct. Stress Analysis, Northrop Aircraft, Inc.

McGowan, Allan A., Engrg. Draftsman "A," Northrop Aircraft, Inc.

Nanevicz, Stanley J., B.S. in Ae.E., Ens., U.S.N.R.; Operations Dept., U.S.S. Kearsarge.

Nichols, Paul M., B. of Ae.E., Ens., U.S.N.R.

Philipp, David A., Engrg. Draftsman "A," Research & Devel. Labs., Electronics Dept., Hughes Aircraft Corp.

Prouty, Richard E., B.S. in Ae.E., Field Serv. Engr., Boeing Airplane Co. (Seattle).

Rada, Robert O., B.S., Aerodynamicist, McDonnell Aircraft Corp.

Rajpaul, Vinod K., B.S. in Ae.E.

Rice, Joseph A., B.S. in M.E., Proj. Engr. 11, Chandler Evans Div., Niles-Bement-Pond Co.

Scherer, James M., B.S.

Sherrill, Robert D., B.S. in Ae.E., 2nd Lt., U.S.A.F.

Shillinger, George L., Jr., B.S., Ens., U.S.N., (U.S.S. Duncan).

Smith, William C., B.S. in Ae.E., Rocket Test Engr., Bell Aircraft Corp.

Sowell, William R., Student, Cal-Aero Technical Institute.

Stoll, Willard L., B. of Ae.E., Assisting Supt., Pre-flight Dept., Kaiser-Frazer Corp.

Tabish, Bernard S., B.S.Ae.E., Engr., Goodyear Aircraft Corp.

Tomich, Louis, B.S., Jr. Research Engr., Continental Aviation & Engrg. Corp.

Tripp, Warren J., 2nd Lt., U.S.A.F.

Ulrich, John R., Jr. Engr.—Stress, Lockheed Aircraft Corp. (Burbank).

Veen, George E., B.A.E., Engr., General Electric Co.

Volet, Leonard, Capt., U.S.A.F.; Aero. Engr., Hq., Air Proving Ground Command, Eglin A.F.B.

Wall, Philip J., B. of Ae.E., Aerodynamics Engr., Consolidated Vultee Aircraft Corp. (San Diego).

Whitaker, Robert H., B.A.E., Engrg. Draftsman "B," Lockheed Aircraft Corp.

Whitehurst, John W., B.S. in Ae.E., Jr. Engr.—Aerodynamics, Stability & Control Group, The Glenn L. Martin Co.

Wilmore, D. O., B.S. in Ae.E., 2nd Lt., U.S.A.F.

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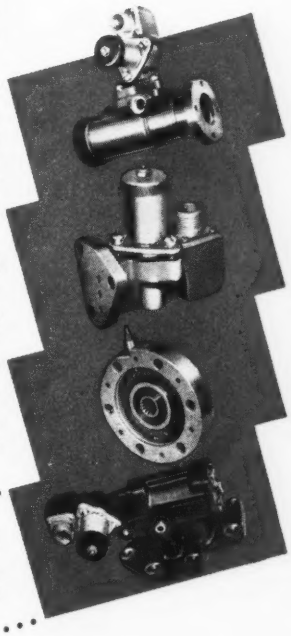

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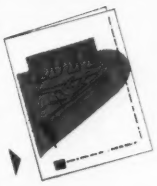

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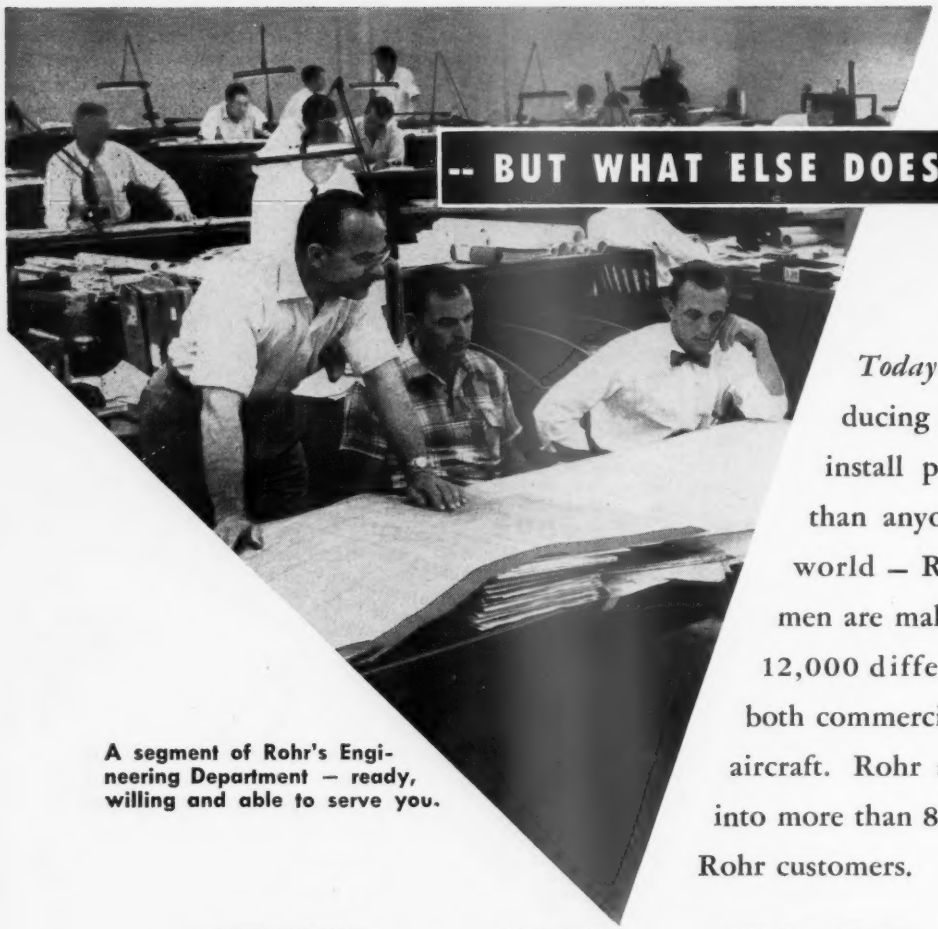

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Aerodynamics (2)

Prophecy and Achievement in Aeronautics. Harry M. Garner. *The Aeroplane*, Vol. 82, No. 2132, May 30, 1952, pp. 663–667, illus. *Flight*, Vol. 61, No. 2262, May 30, 1952, pp. 654–656, illus. (Based on the 40th Wilbur Wright Memorial Lecture, May 29, 1952.) A review of aeronautical progress; aerodynamic studies that have led to improved design and performance of aircraft; future developments.

BOUNDARY LAYER & THERMOAERODYNAMICS

On Pohlhausen's Method with Application to a Swirl Problem of Taylor. J. C. Cooke. *Journal of the Aeronautical Sciences*, Vol. 19, No. 7, July, 1952, pp. 486–490, illus. 16 references.

Investigation of the validity of assuming equal values of δ (boundary-layer thickness) for the velocity components when using Pohlhausen's method to study the three-dimensional boundary layer. A swirl problem of Taylor, which has been solved assuming equal values of δ, is solved using different values for δ, and the solutions are compared.

A Note on the Vortex Patterns in the Boundary Layer Flow of a Swept-Back Wing. Joseph Black. *Royal Aeronautical Society, Journal*, Vol. 56, No. 496, April, 1952, pp. 279–285, illus. 2 references.

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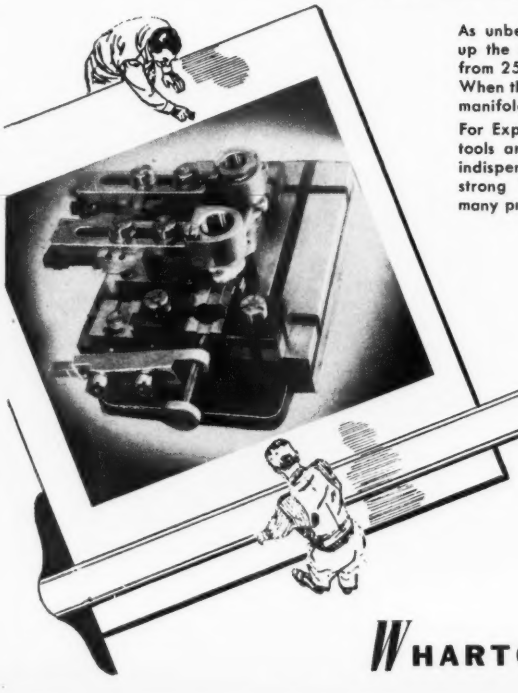

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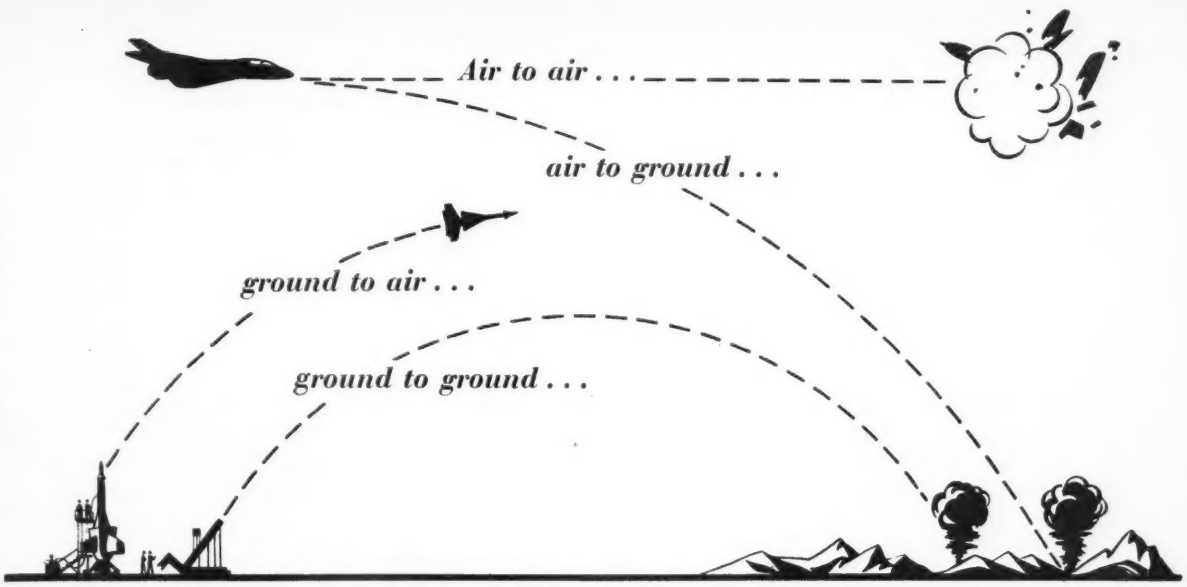

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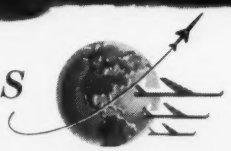
Depend on *DOUGLAS*  **First in Aviation**

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Analysis of isotropic artificial dielectric media that is composed of a three-dimensional cubic array of metal or dielectric spheres. Theoretical expressions are derived for the index of refraction, dielectric constant, and magnetic permeability; measurements, using standard wave-guide techniques, were made at 5,000 mc. per sec. of samples consisting of steel and fused-quartz spheres.

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COMMUNICATIONS

A General Theory of Linear Signal Transmission Systems. L. A. Zadeh. *Franklin Institute, Journal*, Vol. 253, No. 4, April, 1952, pp. 293–311, illus. 20 references.

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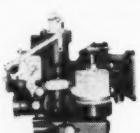

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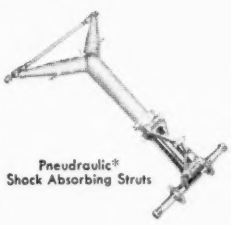

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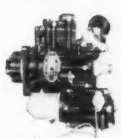

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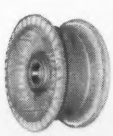

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A general theory of linear signal transmission systems which is based on the resolution of the input signal into a set of elementary or component signals of some suitable but otherwise arbitrary type and contains the usual time domain and frequency domain approaches as special cases.

Letters to the Editor: Physical Entropy and Information. D. A. Bell. *Journal of Applied Physics*, Vol. 23, No. 3, March, 1952, pp. 372–373. 4 references. Analogies that demonstrate the relationship between the negative entropy of information theory and the positive entropy of thermodynamics.

Operational Analysis of Variable-Delay Systems. L. A. Zadeh. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 5, May, 1952, pp. 564–568, illus. 4 references.

Development of an operational method of analysis of variable-delay systems such as delay modulators and variable-path communication systems. The method is essentially an application of the frequency-analysis technique and is based on the use of delay operators involving a variable time-delay.

Service Range for Air-to-Ground and Air-to-Air Communications at Frequencies Above 50 Mc. R. S. Kirby, J. W. Herbstreit, and K. A. Norton. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 5, May, 1952, pp. 525–536, illus. 10 references.

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Microwave Communication System. Ernest A. Dahl. *Radio & Television News*, Vol. 47, No. 5, May, 1952, *Radio-Electronic Engineering*, pp. 16–18, 55–58, illus. Equipment, available frequency bands, and costs of microwave communication systems.

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Electronic Controls as Applied to Aircraft Inverters. Ben Starr. *Aeronautical Engineering Review*, Vol. 11, No. 8, August, 1952, pp. 36–41, illus.

Control circuits that use a gaseous grid controlled-rectifier tube (thyratron) as the control device; operation of the inverter and alternator output voltage controls.

Slope Control for Resistance Welding. W. B. Hills. *Electronics*, Vol. 25, No. 5, May, 1952, pp. 124, 125, illus.

Circuit and operating techniques for a slope control unit for resistance welding. The a.c. welding current is increased gradually from its initial to its final value by back-to-back thyratrons that serve as automatically varying resistors across heat control of the welder; examples of cost-cutting applications.

ELECTRONIC TUBES

Standards on Magnetrons: Definitions of Terms, 1952 (Standard *52* IRE *7* S*1*). *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 5, May, 1952, pp. 562, 563.

Triode Amplifiers for Operation from 100 to 420 Megacycles. D. C. Rogers. *Electrical Communication*, Vol. 29, No. 1, March, 1952, pp. 12–19, illus.

Design features, construction, operation, and applications of triode tubes that can operate at frequencies up to 420 mc. per sec. in grounded-grid circuits, can be mounted on conventional pressed-glass bases, and can be produced by standard manufacturing techniques.

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Efficiency of Thermal Electron Emission. M. J. O. Strutt. *Institute of Radio Engineers, Proceedings*, Vol. 40, No. 5, May, 1952, pp. 601–607, illus. 2 references.

Theoretical calculations of the efficiency of thermal electron emission, defining the efficiency as the ratio of the power imparted to the emitted electrons to the heating power, assuming power loss by radiation only.

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Tube Comparison Chart. J. R. Heck. *Electronics*, Vol. 25, No. 5, May, 1952, pp. 148, 150.

Rapid evaluation of similar types is provided by a three-coordinate graph that compares preferred and representative tube types in terms of plate resistance, transconductance, and amplification factor.

A Simple Valve Comparator. B. C. Foster. *Electronic Engineering*, Vol. 24, No. 291, May, 1952, pp. 220–223, illus. 1 reference.

Circuit and operation of a tube comparator that gives a cathode-ray tube presentation of the anode current versus anode voltage of two tubes simultaneously at a series of grid voltages. The tubes are tested by directly comparing their characteristics with those of a known specimen of the same type.

MEASUREMENTS & TESTING

Apparatus for Testing Transistors. P. J. W. Jochems and F. H. Stieltjes. *Philips Technical Review*, Vol. 13, No. 9, March, 1952, pp. 254–265, illus. 6 references. Development, construction, and operation of an apparatus for tracing various transistor characteristics and measuring the transducer gain.

Microwave Test Equipment. *Radio & Television News*, Vol. 47, No. 5, May, 1952, *Radio-Electronic Engineering*, pp. 34–36, illus. Equipment for making tests and measurements in the 1,000–50,000-mc. range.

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Air-borne apparatus for measuring directly the tropospheric index of refraction fluctuations and profiles. A continuous record of the change in the resonant frequency of a cavity resonator mounted in an aircraft and exposed to atmospheric air provides a record of the atmospheric index of refraction relative to the aircraft.

A Versatile Phase-Angle Meter. G. N. Patchett. *Electronic Engineering*, Vol. 24, No. 291, May, 1952, pp. 224–229, illus. 8 references.

Comparison of the accuracy and applicability of methods employing wattmeters, ammeters, or voltmeters for measuring the phase angle between two electrical quantities; principles, circuit, and operation of a phase-angle meter that gives a direct reading in degrees and positive indication of lagging and leading phase, and operates over the frequency range of 20–20,000 cycles per sec.

NAVIGATION AIDS

Long-Range-Navigation Instrumentation. Ben Alexander. *Electrical Communication*, Vol. 29, No. 1, March, 1952, pp. 9–11. 2 references.

Applications of tests that are used to obtain the accuracy of the instrumentation of the Navaglobe system to the general problem of reducing errors due to noise in the vicinity of the signal and to inaccuracies in the instrument itself in the instrumentation systems for long-range navigation.

Low-Power Beacons for Navigation. *Aviation Week*, Vol. 56, No. 18, May 5, 1952, pp. 49, 50, illus. Australian microwave system plots several stations to fix position; can be used for marking obstacles.

Narco Shows Low-Cost DME Set. Scott H. Reiniger. *Aviation Week*, Vol. 56, No. 18, May 5, 1952, pp. 54, 55, illus.

Design and operation of a lightweight D.M.E. set developed by the National Aeronautical Radio Corp. for personal and corporation aircraft. The D.M.E. set is remote-controlled and has only one knob for the pilot to operate. The Narco Superhomer, also developed for the small-plane market, is a low-cost V.H.F. set that provides the essentials for V.H.F. communication and navigation.

Interplanetary Communications and Navigation. James P. Elliot. *Journal of Space Flight*, Vol. 4, No. 5, May, 1952, pp. 1–6, illus. Use of radar for interplanetary navigation and for the detection of meteors; measurement of velocity by an application of the Doppler effect.

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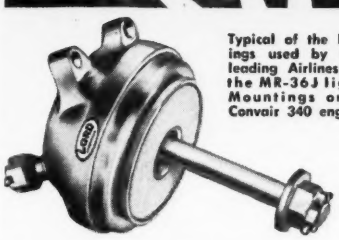

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Navy Unwraps APS-42 Transport Radar. Philip Klass. *Aviation Week*, Vol. 56, No. 19, May 12, 1952, pp. 56–58, 61, 62, 64, illus.

Construction, operating characteristics, and advantages of the AN/APS-42 produced by RCA for the Navy and designed to warn of dangerous terrain and hazardous weather in addition to ground mapping and displaying ground radar beacons to permit offset track flying; comparison with the APS-10.

ATA Seeks Radar with Fewer Frills. Philip Klass. *Aviation Week*, Vol. 56, No. 20, May 19, 1952, pp. 50, 55, 56, 59, 60, 62, illus.

Features recommended by Air Transport Association for a new air-line radar unit that would abandon the X-band for a new wave length in the 5–6-cm. region and concentrate on terrain and weather warning.

Radar Timetable up to the Airlines. Philip Klass. *Aviation Week*, Vol. 56, No. 21, May 26, 1952, pp. 58, 60–62, 64, 65, illus.

Factors that will influence the air lines to decide between a general-purpose radar unit, such as RCA's APS-42 that could be available by mid-1954, and a lightweight warning unit, such as that recommended by the Air Transport Association but not yet developed.

New Ecko One-Man Radar Approach System. *Airports & Air Transportation*, Vol. 5, No. 93, March-April, 1952, pp. 322, 323, illus.

Design details and operation of a prototype radar approach aid that combines a 3-cm. radar installation with a V.H.F. DF receiver, developed for use at airports that do not have sufficient traffic to warrant full-scale equipment.

Radar Plotting Board Controls Air Traffic. *Electronics*, Vol. 25, No. 5, May, 1952, pp. 166, 170, 174, 178, illus. Application of military in-flight radar control techniques to the control of civil aircraft departure; future civil applications.

Organ-Pipe Radar Scanner. K. S. Kelleher and H. H. Hibbs. *Electronics*, Vol. 25, No. 5, May, 1952, pp. 126, 127, illus.

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Predicting Magnetic Amplifier Control Curves. Henry Lehmann. *Electrical Engineering*, Vol. 71, No. 4, April, 1952, p. 311, illus. 1 reference.

A method of analyzing half-wave and full-wave circuits with high control winding impedance for self-saturated magnetic amplifiers, assuming perfect rectifiers and core materials with rectangular hysteresis loops.

TELEMETRY

Guided Missile Test Center. James B. Wynn, Jr., and Sam L. Ackerman. *Electronics*, Vol. 25, No. 5, May, 1952, pp. 106–111, illus.

Construction and operation of the telemetry system adopted as standard for tests on missiles fired at the U.S.A.F. Missile Test Center in the Caribbean. The air-borne equipment can transmit 16 continuous channels of information, six of which may be used on a time-sharing basis to provide up to 172 channels of information.

TRANSMISSION LINES

Chart for the TE_{11} Mode Piston Attenuator. Charles M. Allred. *U.S., National Bureau of Standards, Journal of Research*, Vol. 48, No. 2, February, 1952, pp. 109, 110, illus. 2 references. (Also available as *Research Paper No. 2293*. Superintendent of Documents, Washington. $0.05.) A nomogram for determining the dependence of attenuation on frequency, conductivity, and radius of a cylindrical wave-guide TE_{11} mode piston attenuator.

Specialized Microwave Plumbing. *Radio & Television News*, Vol. 47, No. 5, May, 1952, *Radio-Electronic Engineering*, pp. 14, 15, 52, illus. Equipment, techniques, and new developments in directing microwave energy into and through wave guides, couplers, and cables.

Field Expandability in Normal Modes for a Multilayered Rectangular or Circular Wave-Guide. J. van Bladel. *Franklin Institute Journal*, Vol. 253, No. 4, April, 1942, pp. 313–321, illus. 5 references.

WAVE PROPAGATION

Non-Communications Applications of Microwaves. Samuel Freedman. *Radio & Television News*, Vol. 47, No. 5, May, 1952, *Radio-Electronic Engineering*, pp. 11–13, 62, 63, illus. Applications of microwaves to D.M.E., radar (including G.C.A.), calorimetry and spectroscopy.

Equipment

Contributors to Success. *The Aeroplane*, Vol. 82, No. 2128, May 2, 1952, pp. 547–549, illus. Design features of equipment and accessories developed by various companies for the de Havilland Comet.

ELECTRIC (16)

400-Cycle Aircraft Electric Systems. Karl W. Carlson. *Aero Digest*, Vol. 64, No. 4, April, 1952, pp. 46, 48, 50, 52, 54, 56–58, illus.

Operational details of a.c. systems developed by General Electric for aircraft use; problems connected with the use of a.c. systems in aircraft; applications; construction and operation of 400-cycle a.c. systems; comparison with d.c. systems.

HYDRAULIC & PNEUMATIC (20)

Airline Experience with Hydraulic Fluids. *Applied Hydraulics*, Vol. 5, No. 5, May, 1952, pp. 76, 78, 80, 82, 84, 86.

Operational experience, reported by the air lines, the U.S.N., and the U.S.A.F., with nonflammable and conventional hydraulic fluids; effect of both types of fluid on the service life of hydraulic-system components and on hydraulic seals.

Analysis of Some Hydraulic Components Used in Regulators and Servomechanisms. S. Z. Dushkes and S. L. Cahn. *American Society of Mechanical Engineers, Transactions*, Vol. 74, No. 4, May, 1952, pp. 595–601, illus. Theory of operation and static and dynamic characteristics of some hydraulic components.

Trapped Air in Hydraulic Systems. J. E. C. Stringer and K. N. Hastings. *Applied Hydraulics*, Vol. 5, No. 5, May, 1952, pp. 57, 58, 112, 113, illus. 1 reference.

Circuit problems resulting from trapped air in hydraulic systems; construction and operation of the Bubblicator, an instrument developed for measuring air in oil, and of a manually operated air-release valve for removing air from hydraulic pipes.

Cavitation Mechanics in the Design of Hydraulic Equipment. II, III. Robert T. Knapp. *The Engineer*, Vol. 193, Nos. 5023, 5024, May 2, 9, 1952, pp. 592–596; 627, 628, illus.

How to Design Hydraulic Reservoirs. W. T. McCormick. *Applied Hydraulics*, Vol. 5, No. 5, May, 1952, pp. 64–66, illus.

Flight Safety & Rescue (15)

Some Developments for Greater Crash Safety in Aircraft. Robert J. Schroers. *SAE Quarterly Transactions*, Vol. 6, No. 2, April, 1952, pp. 241–251, illus.

Equipment, facilities, procedures, and results of simulated crash tests on the flexible bladder-cell fuel tank. The tests were undertaken to develop fuel tanks capable of withstanding a crash impact range of 15 to 30 *g*.

Current Safety Considerations in the Design of Passenger Seats for Transport Aircraft. Hugh De Haven. *New York, Cornell University Medical College, Crash Injury Research*, June, 1952. 12 pp. 7 references. Features of seat design which contribute to passenger protection and safety in survivable air-transport accidents.

The Suppression of Explosions. E. J. White. *Society of Licensed Aircraft Engineers, Journal*, Vol. 1, No. 3, March, 1952, (*Technical Instructor*, Vol. 7, No. 3), pp. 18, 19.

Development and operation of a suppression system for fuel explosions in which a detector gives immediate response to a pressure rise developing from an explosion and electrically exploded containers scatter inhibiting fluid in the path of the explosion flame front.

New Ditching Survival Plan Urged. F. Lee Moore. *Aviation Week*, Vol. 56, No. 19, May 12, 1952, pp. 84–87, illus. Results of C.A.B.'s investigation of passenger survival of water landings; possible application to survival equipment and methods.

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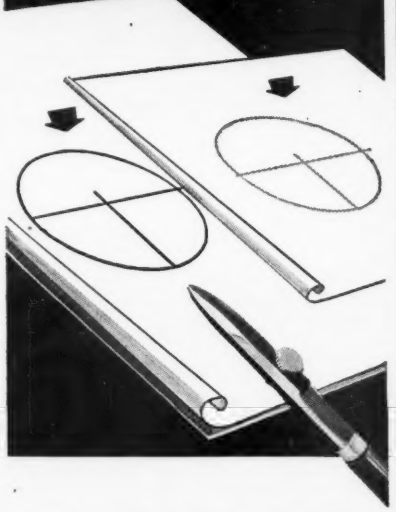

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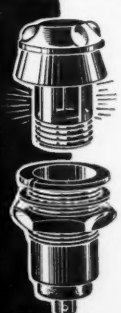

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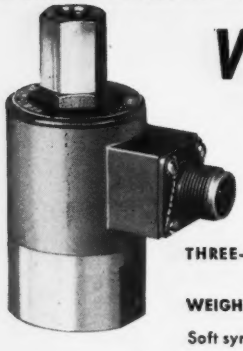

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Flight Testing (13)

Production Test Flying. H. P. Powell. *Shell Aviation News*, No. 166, April, 1952, pp. 7–10, illus. Planning and procedures for flight-testing production aircraft.

Fastest and Highest. *Flight*, Vol. 61, No. 2259, May 9, 1952, pp. 556–558, illus. Results and analysis of supersonic flight tests by William B. Bridgeman on the Douglas D-558-II Skyrocket; air-launching techniques.

Fuels & Lubricants (12)

The Aviation Industry. *Lubrication*, Vol. 38, No. 4, April, 1952, pp. 37–52, illus. 9 references.

Significant development in fuels and lubricants for aircraft and power plants; results of a service evaluation on additive oils for reciprocating engines; lubrication needs and problems of gas-turbine engines; commercial jet fuels; aircraft and accessory lubricants; lubricating oils and hydraulic fluids.

How Gasoline Helps to Form Engine Deposits. R. S. Spindt and Court L. Wolfe. *SAE Journal*, Vol. 60, No. 5, May, 1952, pp. 39–44, illus. (Excerpts from a paper.) Equipment, procedure, and results of experiments on the role of gasoline in the formation of engine deposits.

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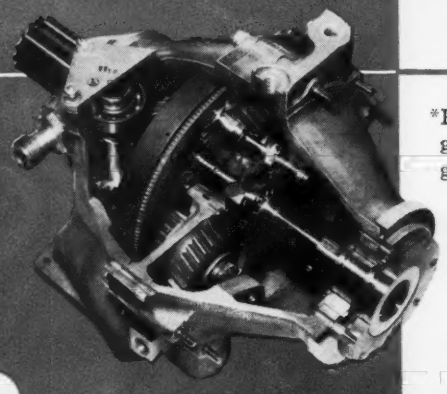

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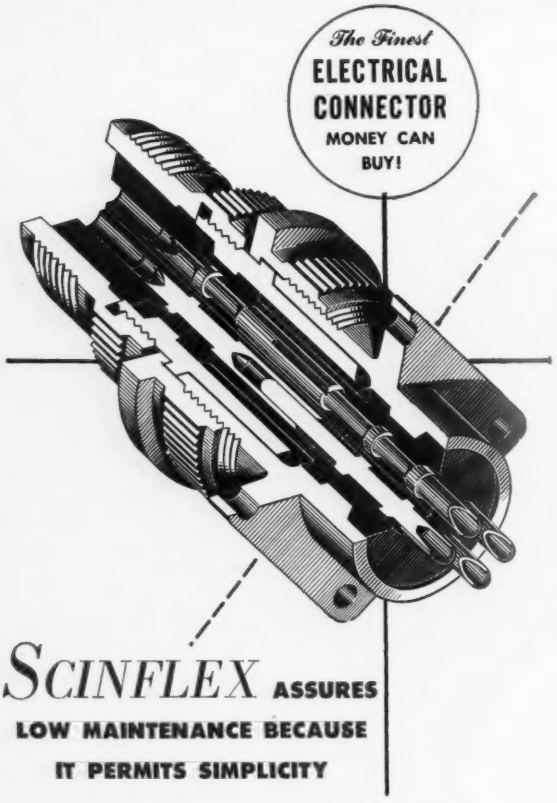

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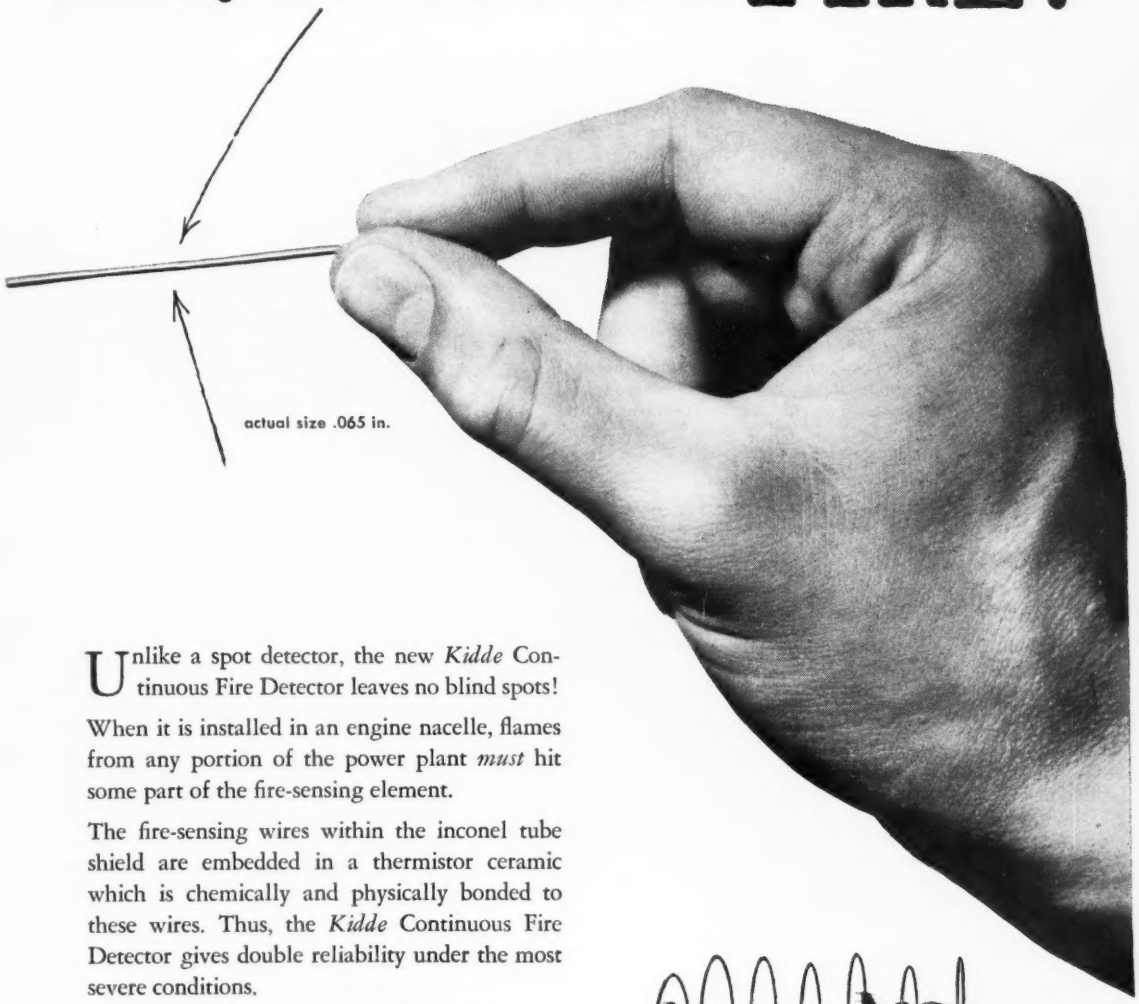

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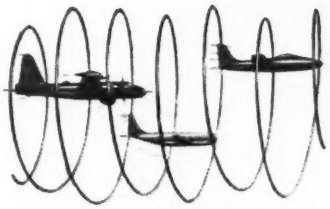

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NONMETALLIC MATERIALS

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Missiles (1)

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Construction and operation of the equipment used in the telemetry system adopted as standard for tests on missiles fired at the U.S.A.F. Missile Test Center in the Carribbean.

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The Selection of Navigation Systems for Military Aircraft. D. Bower. *Institute of Navigation, Journal*, Vol. 5, No. 2, April, 1952, pp. 147–167, illus. 3 references.

Factors that affect the selection of navigation systems for both strategic and tactical uses of military aircraft in all phases of the mission; flexibility, mobility, and security requirements.

Flight Navigation Techniques Across the Pacific. Robert S. Nielsen. *Navigation*, Vol. 3, No. 3, March, 1952, pp. 84–89.

Flight navigation techniques and available ground and airborne navigation equipment for a flight plan from Sydney, Australia, to Vancouver, Canada, via Fiji, Canton Island, Honolulu, and San Francisco.

The Design of Aeronautical Charts. Rolland H. Waters and Edward W. Bishop. *Navigation*, Vol. 3, No. 3, March, 1952, pp. 73–78. 12 references. Principles and techniques of chart design which would increase the functional value of aeronautical charts.

A Twilight Computer and Planisphere for High Latitude Navigation. J. W. Cox and K. R. Greenaway. *Navigation*, Vol. 3, No. 3, March, 1952, pp. 67–73, illus.

Theory, design, and accuracy of a computer for calculating the twilight conditions on any flight path; the computer, which con-

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Ordnance & Armament (22)

Russian Aircraft Guns. I. Roger Marsh. *Aviation Age*, Vol. 17, No. 5, May, 1952, pp. 34, 35, illus. Types, construction, and operation of Soviet aircraft armaments.

Photography (26)

A Simplified Method of Measuring Take-Off Distances. G. C. Abel. *Aircraft Engineering*, Vol. 24, No. 279, May, 1952, pp. 132, 133, 145, illus. 1 reference. A method of analysis of F.47 camera films of take-offs, based on a fixed position of the camera on the runway.

Aussies Make Recording Camera. *Aviation Week*, Vol. 56, No. 21, May 26, 1952, p. 68, illus.

Features and advantages of an operational research camera developed by the Australian Department of Civil Aviation which records take-off and landing performance and gives data for computing normal rates of acceleration and deceleration during take-off and landing, and normal touchdown speed.

Development of an Instrument for Measuring Aircraft Cockpit Visibility Limits. Thomas M. Edwards. *U.S., C.A.A., Technical Development Report No. 153*, January, 1952. 8 pp., illus. 7 references.

Design, development, and operation of the Binocular Cockpit Visibility Camera designed for use as a standard means of measuring and recording cockpit vision angles; comparison with other instruments used for the same purpose. The camera has two lenses spaced at the average distance between the human eyes and records both visibility and angles of vision in the cockpit.

Automatic Exposure Control. George Bruck and John Ward. *Photographic Engineering*, Vol. 3, No. 1, 1952, pp. 1–11, illus.

An electronic control that provides continuous adjustments of exposure by regulating the iris and shutter-speed; applications to strip-film cameras for high-speed, low-altitude aerial photography.

Initial Adjustment of the Mach-Zehnder Interferometer. E. W. Price. *Review of Scientific Instruments*, Vol. 23, No. 4, April, 1952, p. 162, illus. 3 references.

Power Plants

ATOMIC

The Promise and Problems of Atomic Power. Gale Young. *Aeronautical Engineering Review*, Vol. 11, No. 8, August, 1952, pp. 22–29, 52, illus. 18 references.

Scope of the operations of the U.S. Atomic Energy Commission; progress in basic and applied atomic-power research; the advantages of a breeder-reactor as compared with fission-chain reactors; problems in the development of atomic power for military and commercial uses; atomic propulsion of aircraft.

JET & TURBINE

Thrust Augmentation. II, III. S. G. Allerton. *Society of Licensed Aircraft Engineers, Journal*, Vol. 1, Nos. 2, 3, February, March, 1952 (*Technical Instructor*, Vol. 7, Nos. 2, 3), pp. 14, 15; Discussion, pp. 19, 20, illus. Methods of thrust augmentation by water methanol or ammonia injection into the compressor and by use of an afterburner.

Theoretical Augmentation of Turbine-Propeller Engine by Compressor-Inlet Water Injection, Tail-Pipe Burning, and Their Combination. Reece V. Hensley. *U.S., N.A.C.A., Technical Note No. 2672*, March, 1952. 43 pp., illus. 6 references.

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Arrival of Jet Power Brings New Language. J. W. Tomlinson. *Canadian Aviation*, Vol. 25, No. 5, May, 1952, pp. 34, 35, 56, illus. Definition of terms used for the components of the axial-flow Avro Orenda and the centrifugal-flow Rolls-Royce Nene jet engines produced in Canada.

The Light Turbojet in France. *Esso Air World*, Vol. 4, No. 5, March-April, 1952, pp. 132, 133, illus.

Construction and performance of the small low-powered gas turbines produced in France for aircraft propulsion and other aviation uses by the Établissements Fouga and the Société Turboméca.

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Running Mate of Orenda; Nene to Power Trainers. *Canadian Aviation*, Vol. 25, No. 5, May, 1952, pp. 36, 38, 58–61, illus. Construction and operation of the Rolls-Royce Nene that will be used to power the Lockheed T-33 jet trainer.

The (Armstrong Siddeley) Mamba Engines in the (Armstrong Whitworth) Apollo Aircraft. B. H. Slater. *American Society of Mechanical Engineers, Transactions*, Vol. 74, No. 2, February, 1952, pp. 247–250, Discussion, pp. 251–253, illus. Performance characteristics, installation problems, operation, and flight experience.

Lessons Taught by Turboprop Viscount. David A. Anderton. *Aviation Week*, Vol. 56, No. 19, May 12, 1952, pp. 25, 26, 29, 30, 35, 36, illus.

Construction and operation of the four Rolls-Royce Dart 505 R. Da3 turboprop engines that power the Vickers 700 Viscount prototype; each engine gives 1,530 lbs. thrust at sea level; results of flight experience.

Jet Aircraft Fuel Systems. J. E. Walker. *The Aeroplane*, Vol. 82, No. 2129, May 9, 1952, p. 563. *Flight*, Vol. 61, No. 2258, May 2, 1952, pp. 531, 532, illus.

An analysis of the fundamental principles, procedures for testing fuel-system components before and after installation, and fuel types and detail design of components of gas-turbine fuel systems.

Evaluation of Three Methods for Determining Dynamic Characteristics of a Turbojet Engine. Gene J. Delio. *U.S., N.A.C.A., Technical Note No. 2634*, February, 1952. 56 pp., illus. 12 references.

Analysis of data from approximate step and sinusoidal disturbances of turbojet-engine fuel flow by three methods: transient analysis for obtaining the coefficients of the differential equations; Fourier analysis of the transient data, and a.c. analysis using steady-state frequency response data; evaluation and comparison of the three methods for obtaining turbojet-engine dynamic characteristics.

A Simplified Theory of Jet Propulsion. J. Lockwood Taylor, *Aircraft Engineering*, Vol. 24, No. 279, May, 1952, p. 131.

A procedure for calculating jet-engine performance, based on simplified assumptions for the engine parameters; this method gives results in good agreement with known data.

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An Instantaneous and Continuous Sodium-Line Reversal Pyrometer. M. M. El Wakil, P. S. Myers, and O. A. Uyehara. *American Society of Mechanical Engineers, Transactions*, Vol. 74, No. 2, February, 1952, pp. 255–264, Discussion, pp. 265–267, illus. 25 references.

Theory, development, and calibration of an electro-optical sodium-line reversal pyrometer for measuring and recording combustion temperatures in a spark-ignition engine.

Research in Exhaust Manifolds. P. H. Schweitzer. *American Society of Mechanical Engineers, Transactions*, Vol. 74, No. 4, May, 1952, pp. 517–528, illus. 8 references. Outline of the experimental apparatus and techniques used in a study of the effect of the exhaust manifold on engine performance; summary of test data.

A New Aviation Fuel Lead Scavenger. V. E. Yust. *Aero Digest*, Vol. 64, No. 4, April, 1952, pp. 76, 78, 80, illus. Development and results of tests on the lead scavenger developed by Shell Oil Co. to reduce spark-plug fouling.

ROCKET (4)

The Design of Rocket Motors. D. Hurden. *British Interplanetary, Society, Journal*, Vol. 11, No. 3, May, 1952, pp. 101–116, illus.

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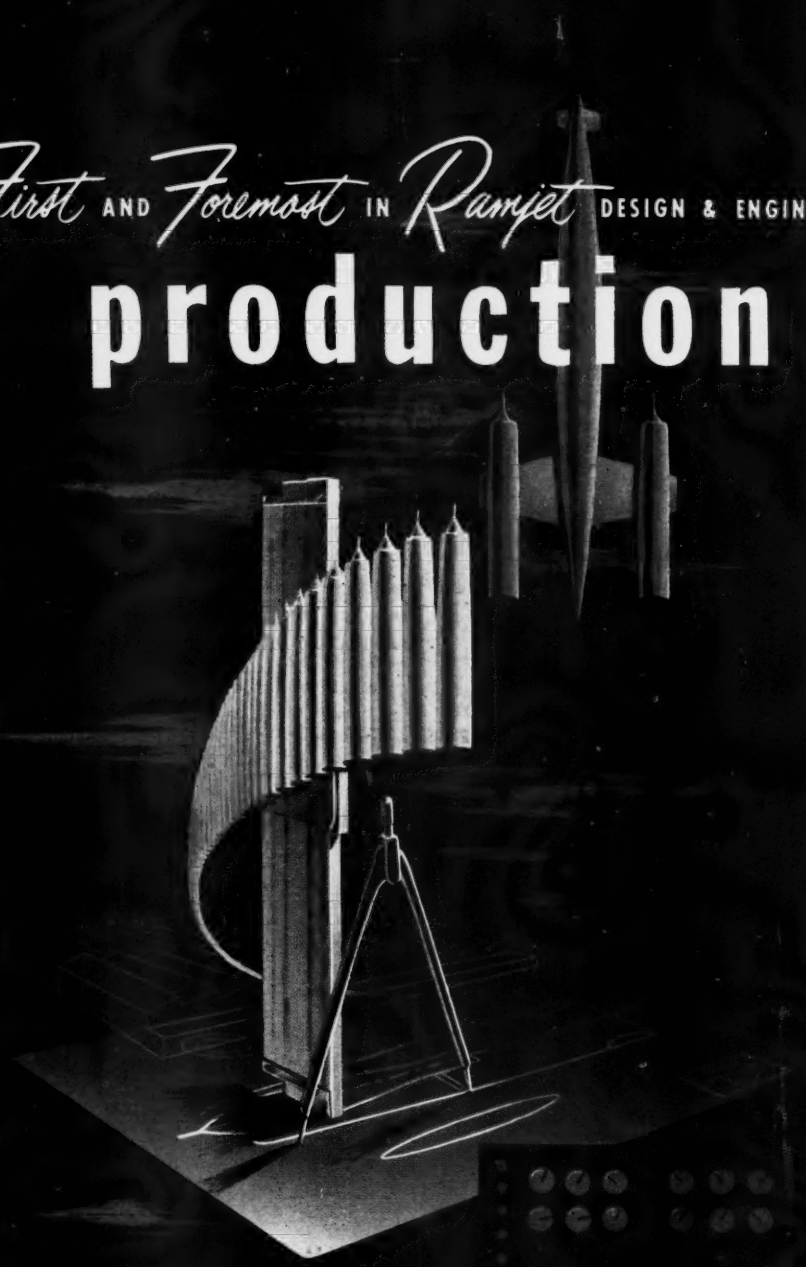

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The process of designing a liquid-fuel rocket motor; design and selection of components and calculation procedures for estimating their characteristics; importance of avoiding cavitation in the turbine and pump.

Discussion on "Stability of Flow in a Rocket Motor" by D. F. Gunder and D. R. Friant. S. Sherman. *Journal of Applied Mechanics*, Vol. 19, No. 1, March, 1952, pp. 125, 126. 6 references. A solution for the roots of the equation for the stable operation of a bipropellant liquid-fuel rocket motor.

The Transfer Functions of Rocket Nozzles. H. S. Tsien. *American Rocket Society, Journal*, Vol. 22, No. 3, May-June, 1952, pp. 139–143, 162, illus. 4 references. Definition of the transfer function in rocket nozzles; calculation as a function of the frequency of oscillation.

A Comparison of Adiabatic and Isothermal Expansion Processes in Rocket Nozzles. H. S. Seifert and D. Altman. *American Rocket Society, Journal*, Vol. 22, No. 3, May-June, 1952, pp. 159–162. 6 references.

Fluctuations in a Spray Formed by Two Impinging Jets. Marcus F. Heidmann and Jack C. Humphrey. (*U.S., N.A.C.A., Technical Note No. 2349*, April, 1951.) *American Rocket Society, Journal*, Vol. 22, No. 3, May-June, 1952, pp. 127–131, 167, illus. 4 references.

Study of the hydraulic characteristics of the injector as a possible source of high-frequency instability of a liquid-propellant rocket motor. Photographs and charts show the results of an investigation of the spray fluctuations in two impinging jets of water.

Injector Spray and Hydraulic Factors in Rocket Motor Analysis. Kurt R. Stehling. *American Rocket Society, Journal*, Vol. 22, No. 3, May-June, 1952, pp. 132–138, illus. 8 references. Comparison of various types of thrust-chamber injection systems; techniques and equipment for injector research.

Heat Flow in Composite Slabs. E. Mayer. *American Rocket Society, Journal*, Vol. 22, No. 3, May-June, 1952, pp. 150–158, illus. 5 references. Mathematical presentation of the temperature transients in a composite slab corresponding to the heat-transfer conditions in a rocket motor.

Production (36)

Canada's Aircraft Industry. III, IV, V. James Hay Stevens. *Flight*, Vol. 61, Nos. 2258, 2259, 2261, May 2, 9, 23, 1952, pp. 538, 539; 554, 555; 629, 630 illus. Organization, design and production techniques, and aircraft types produced in Canada at Avro, Canadair, and de Havilland.

Aircraft Production in Italy. *The Aeroplane*, Vol. 82, No. 2231, May 23, 1952, pp. 628–632, illus. Italian aircraft companies; their production progress; types of aircraft produced since World War II; connections with aircraft companies in other countries.

Stripping of Electrodeposits. R. H. Keller. *Australia, Defence Research Laboratories, Information Circular No. 16*, September, 1951. 23 pp. 15 references. Reprint.

A summary of published material on the solutions and methods for stripping brass, bronze, cadmium, chromium, copper, gold, lead, nickel, palladium, platinum, rhodium, silver, speculum, tin, and zinc from the base metals on which they are usually plated.

New Techniques Build Prewitt's Rotors. David A. Anderton. *Aviation Week*, Vol. 56, No. 18, May 5, 1952, pp. 22–24, illus.

Development, equipment, techniques of producing and assembling an all-metal completely hollow rotor blade designed by the Prewitt Aircraft Co. for the Piasecki HUP-2 twin-rotor helicopter; results of flight tests on the HUP-2 with these rotors.

Hydraulic Piercing Machine. *Aircraft Production*, Vol. 14, No. 163, May, 1952, pp. 168, 169, illus.

Construction and operation of an hydraulic machine for piercing gas-turbine shroud rings developed for the de Havilland Engine Co., Ltd. The machine operates on a completely automatic cycle and is adaptable to piercing operations on similar parts.

Rotary Stretch-Forming. *Aircraft Production*, Vol. 14, No. 163, May, 1952, pp. 183, 184, illus. 1 reference.

Construction and operation of the Radial Draw Former developed by the Cyril Bath Co. for forming circular, elliptical, or rectangular forms from section or sheet material.

Specialty Die Designs for Stamping and Forming. II—The Guerin Process. Lester F. Spencer. *Steel Processing*, Vol. 38, No. 4, April, 1952, pp. 180–185, 190, 191, 194, illus. 6 references.

Operations in Extruding Hollow Steel Propeller Blades. *Automotive Industries*, Vol. 106, No. 10, May 15, 1952, pp. 37, 38, illus.

Details of the hot-extrusion process, used at Curtiss-Wright Corp., for producing 10-ft. hollow steel propeller blades from 400-lb. Cr-Ni-Mb steel billets. Drawings show the various steps of the process.

Low-Cost Jet Blades for Future. *Aviation Week*, Vol. 56, No. 21, May 26, 1952, pp. 42, 44, illus. Summary of a survey of the costs and new methods of jet-engine blade production; evaluation of the cold-rolling process.

Skin-Milling. *Aircraft Production*, Vol. 14, No. 163, May, 1952, pp. 170–175, illus. 3 references.

Structural features, methods of operation, and applications of the Giddings and Lewis Type 100 milling machine with a table work-load capacity of up to 1,000 lbs. per sq.ft. and a table drive that can traverse work loads of up to 300,000 lbs. at approximately 6 ft. per min., developed for milling integrally reinforced aircraft skins from solid sheets or rough aluminum-alloy forgings.

Machining Data of High Temperature Alloys. P. G. DeHuff and D. C. Goldberg. *Automotive Industries*, Vol. 106, No. 9, May 1, 1952, pp. 46–49, 82, 86, illus. Physical, mechanical, and machining properties of high-temperature alloys and their effects on machine-tool life; application of various alloys to jet-engine parts.

Machining Magnesium Alloys. *Magazine of Magnesium*, May, 1952, pp. 10–15, illus.

Power required, tool materials and tool design, and coolants for machining magnesium and its alloys. Tables give data on tool selection, maximum allowable depth of cut, and speed for various machining operations.

How to Hot-Form a Dimple; Method Avoids Cracking in Rivet Hole Forming. Thomas A. Dickinson. *Steel Processing*, Vol. 38, No. 4, April, 1952, pp. 172–174, illus.

Automatic Welding with Contact Electrodes. W. P. van den Blink, H. Bienfait, and J. A. van Bergen. *Philips Technical Review*, Vol. 13, No. 9, March, 1952, pp. 247–253, illus. 3 references. Fundamental principles of welding with contact electrodes; construction, operation, and evaluation of the automatic contact-welding machine.

Ryan Welds Giant External Tanks. *Aviation Week*, Vol. 56, No. 18, May 5, 1952, p. 29, illus.

Equipment and cleaning and welding techniques used at Ryan Aeronautical Co. for the production of large cylinders smoothed by more than 30,000 electric spot welds for external fuel tanks.

Glass Forming-Tools. J. Rees and P. K. Digby. *Aircraft Production*, Vol. 14, No. 163, May, 1952, pp. 148–150, illus. 1 reference.

Production, applications, and advantages of glass beating-blocks, rubber-die press-tools, and drop-hammer tools developed by the Bristol Aeroplane Co., Ltd., for their use in producing small quantities of components from light-alloy sheet.

Increasing Productivity in Production Machining. Michael Field and Norman Zlatin. *SAE Quarterly Transactions*, Vol. 6, No. 2, April, 1952, pp. 196–212, illus. 3 references. Procedures for increasing rates of production in machining by reducing the time actually necessary to machine the metal.

Engineering Your Company's Future. *Product Engineering*, Vol. 23, No. 5, May, 1952, pp. 151–226, illus.

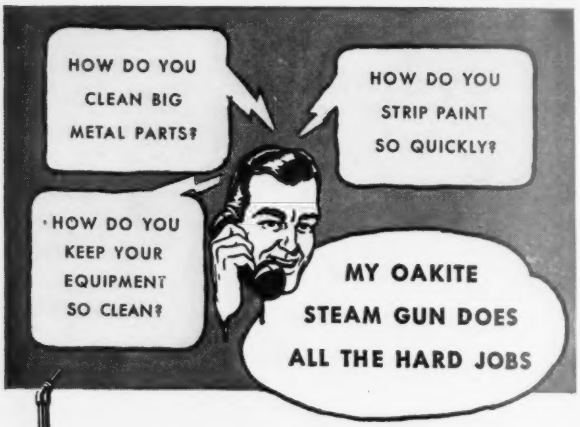
An Analysis of Cost Estimating Principles and Practices. I. Lawrence E. Doyle. *Tool Engineer*, Vol. 28, No. 5, May, 1952, pp. 37–40, illus.

Engineering Features of the D.H. 106. *The Aeroplane*, Vol. 82, No. 2128, May 2, 1952, pp. 524–528, illus. Engineering features and methods used in the construction and layout of components of the de Havilland Comet.

The Wheelon Press. *Western Aviation*, Vol. 32, No. 5, May, 1952, pp. 12, 13, illus.

Specifications, operation, and applications of the Wheelon Direct Hydraulic Rubber Pad Press that is used for the shallow-forming of aluminum and other sheet metals at Douglas Aircraft Co. The Wheelon Press is approximately $^1/_{10}$ the size of the conventional hydropress and is rated at 2,500 tons at 5,000 lbs. per sq.in. operating pressure.

Small Press Designed for Big Job. *Aviation Week*, Vol. 56, No. 19, May 12, 1952, pp. 44, 45, illus. Construction, operation, and performance of the Wheelon prototype direct-acting hydropress; comparison of operating costs with that of conventional and more expensive aircraft hydropresses.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Oil Jet Hits Spot, Stretches Tool Life. *Aviation Week*, Vol. 56, No. 20, May 19, 1952, pp. 39, 40, 42, 45, illus.

Development of a method for cooling and lubricating metal-cutting tools which uses small jets of oil positioned beneath the tool-workpiece contact point; test results; applications.

Propellers (11)

The Variable Pitch Propeller. L. G. Fairhurst. *Shell Aviation News*, No. 166, April, 1952, pp. 14–18, illus. Scope of future applications of the variable pitch propeller; construction and control problems involved.

Operations in Extruding Hollow Steel Propeller Blades. *Automotive Industries*, Vol. 106, No. 10, May 15, 1952, pp. 37, 38, illus. Details of the hot-extrusion process, used at Curtiss-Wright Corp., for producing 10-ft. hollow steel propeller blades from 400-lb. Cr-Ni-Mb steel billets.

Airscrew-Hub Manufacture. II—Machining the Driving-Centre; Assembly Operations. *Aircraft Production*, Vol. 14, No. 163, May, 1952, pp. 176–182, illus. 1 reference.

Reference Works (47)

Natural Flight and Related Aeronautics. James L. G. Fitz Patrick. *Institute of the Aeronautical Sciences, Sherman M. Fairchild Fund, Paper No. FF-7*, June, 1952. 118 pp., illus. 1,978 references. Members, $2.65; nonmembers, $3.50.

A bibliography of 1,978 references on natural flight and related aeronautics arranged alphabetically by year of publication from 400 B.C. through January, 1952; introduction and explanation are in English, French, and German; alphabetical indexes for authors, subjects, and inventors, including the patent number for their inventions and the country and year in which the patent was granted; appendix covers additional patents grouped by country.

Microwave Index. *Radio & Television News*, Vol. 47, No. 5, May, 1952, *Radio-Electronic Engineering*, pp. 61, 62.

An alphabetically arranged index, grouped by year of publication and covering the period from 1943 through 1951, of feature articles on microwaves which have appeared in the *Radio-Electronic Engineering* section of *Radio & Television News*.

A Dictionary of Metallurgy. III. A. D. Merriman and J. S. Bowden. *Metal Treatment*, Vol. 19, No. 79, April, 1952, pp. 175–182, illus.

24th Annual Directory Number; American Aircraft and Engines, with Manufacturing Personnel. *Western Aviation*, Vol. 32, No. 4, April, 1952. 106 pp., illus., tables.

Photographs and specifications of U.S. Military and civil aircraft and of U.S. aircraft engines; alphabetical directory of aircraft and engine manufacturers which lists their corporate name, address, and key personnel.

Planes of the USAF. *Skyways*, Vol. 11, No. 6, June, 1952, pp. 17–35, illus., tables. Photographs and specifications of the U.S.-A.F. bomber, fighter, special purpose, and transport aircraft, and helicopters.

Commercial Aviation. *Flight*, Vol. 61, No. 2260, May 16, 1952, pp. 585–613, illus.

Alphabetical list of British independent air lines that operate scheduled services under agreements with B.E.A., B.O.A.C., or the Government, number and types of their aircraft, and services offered; alphabetical list of the world's scheduled air-line operators which includes their corporate name, headquarters, number and types of aircraft, air routes and mileage, and grade of I.A.-T.A. membership; specifications, performance, pay load, and operating costs of the world's commercial aircraft, classified according to their gross weights; comments on their services by the heads of 15 of the world's air lines.

Directory of Microwave Equipment Manufacturers. *Radio & Television News*, Vol. 47, No. 5, May, 1952, *Radio-Electronic Engineering*, pp. 48, 50. An alphabetically arranged directory of microwave equipment manufacturers which lists their names, addresses, and type of equipment produced.

Rotating Wing Aircraft (34)

Trends in Helicopters. Igor Sikorsky. *SAE Journal*, Vol. 60, No. 5, May, 1952, pp. 17, 18, illus. (Excerpts from a paper.)

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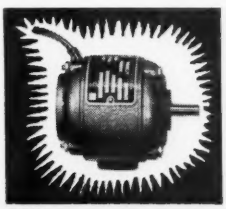

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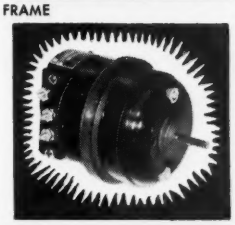

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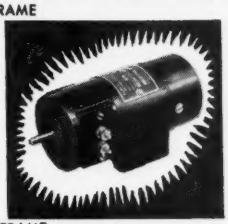

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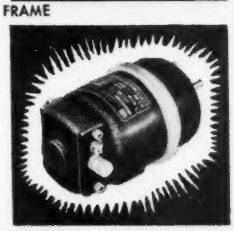

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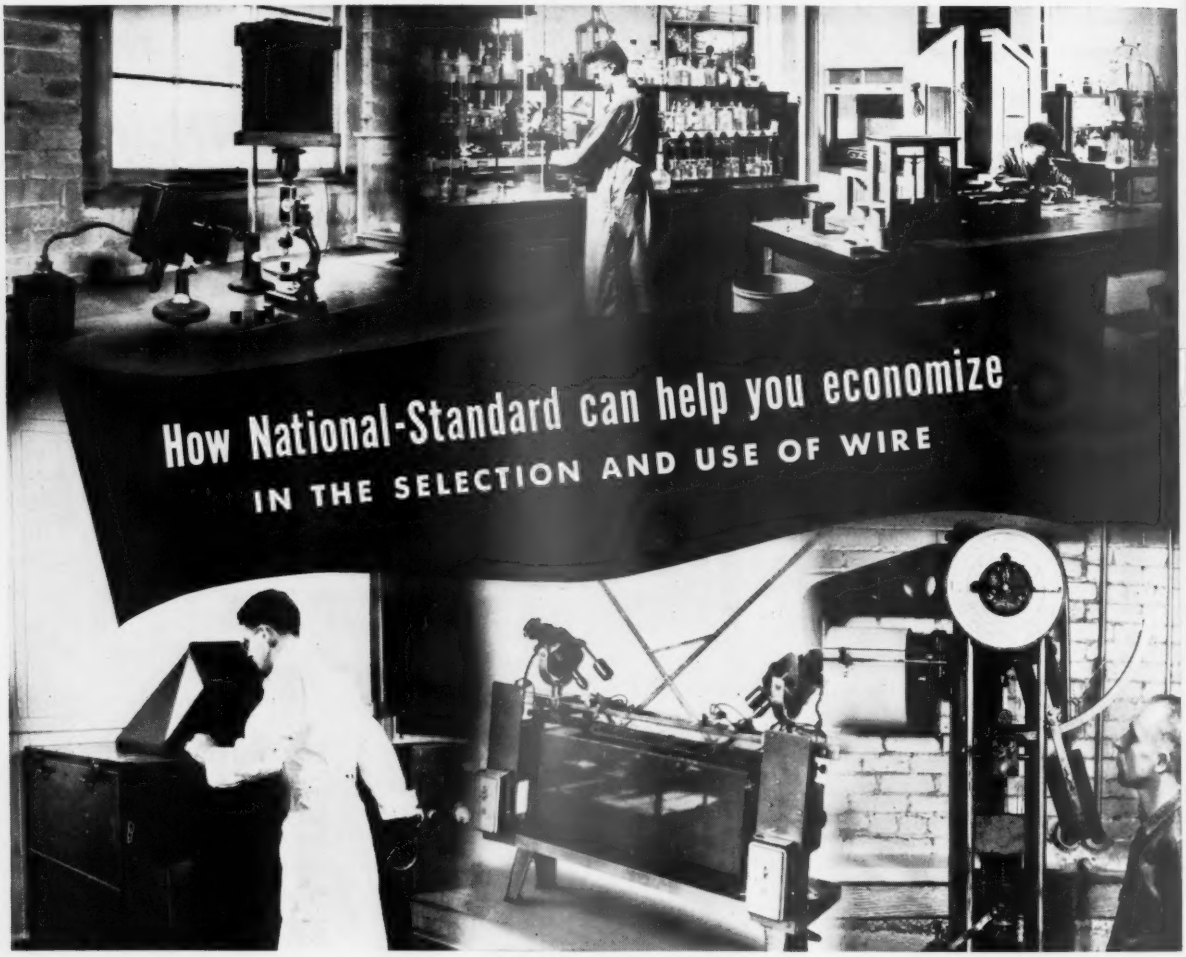

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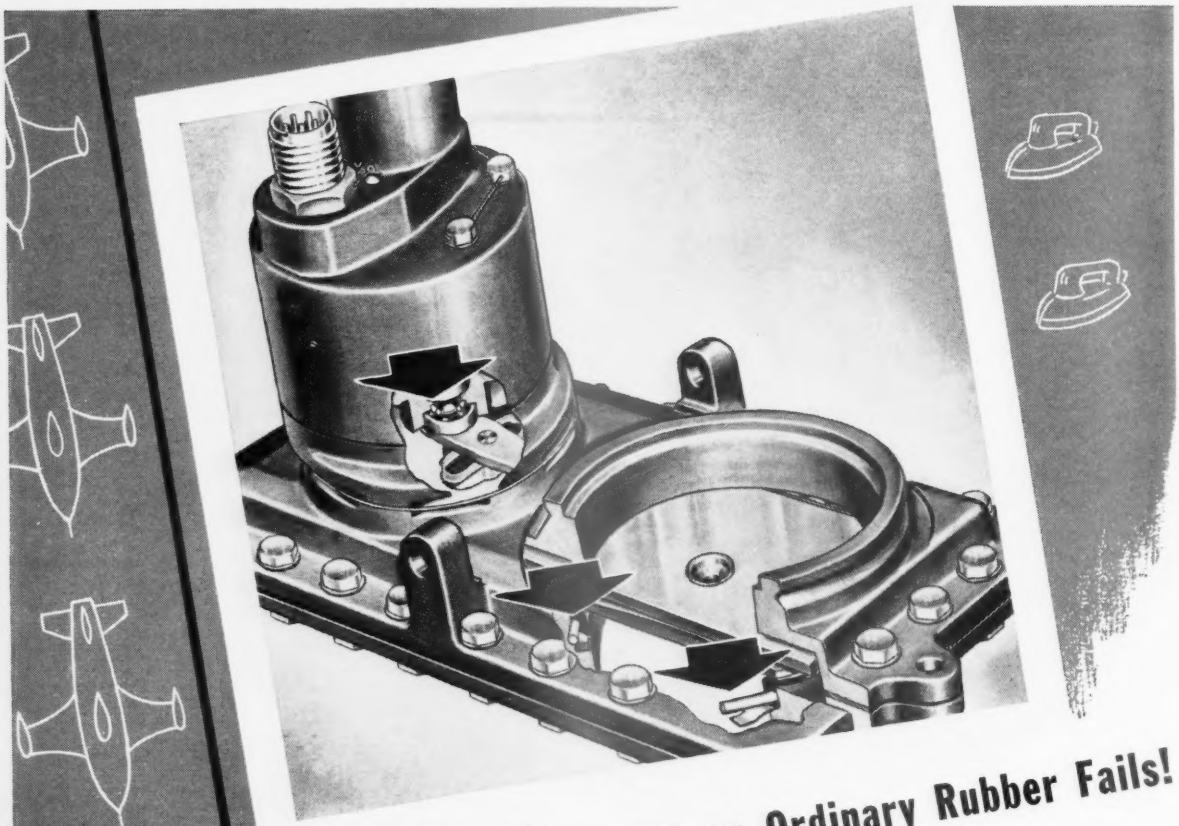

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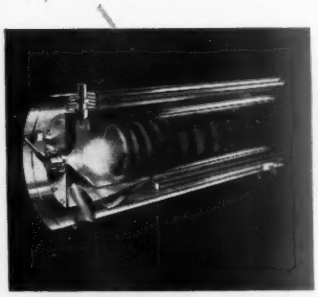

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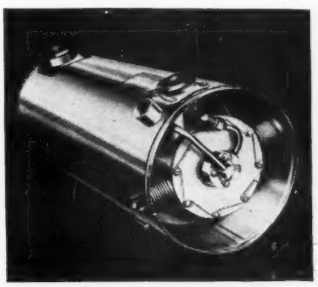

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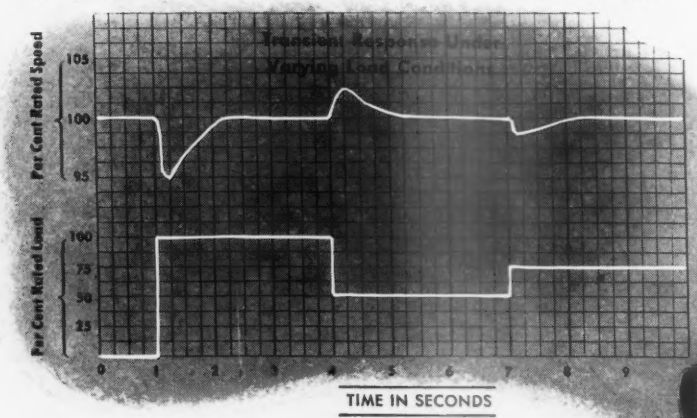

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Aeronautical Reviews — BOOKS

Aerodynamics of the Helicopter

By Alfred Gessow and Garry C. Myers, Jr. New York, The Macmillan Company, 1952. 343 pp., figs. $6.00.

This is a book that should be read by all members of the helicopter industry who are interested in aerodynamics, rotor design, and performance. The authors have summarized N.A.C.A. rotary-wing research from the earliest autogiro days through 1950. They have presented the material in usable form and augmented it with many convincing physical explanations.

Helicopter performance analysis has been dominated for a long time by the formidable reports of Messrs. John B. Wheatley and F. J. Bailey, Jr., of the N.A.C.A. To me, the Wheatley-Bailey analysis always appeared complicated, with involved charts and lengthy calculations. Perhaps the best part of the Gessow-Myers book is that which deals with these Wheatley-Bailey reports. The reader is led by the hand through the forest of complications and emerges with a simple and concise knowledge of the terrain. However, I cannot share the authors' enthusiasm for extreme refinements in hovering efficiency and was not convinced by the arguments in favor of the 8H12 airfoil section, especially since the reduction in drag coefficient shown on page 246 cannot be realized in practice. Also, even for a book on the subject of aerodynamics, there is insufficient emphasis on the weight problem and too much emphasis on the rotor considered as an isolated unit. For example, a reduction in CT/σ to a value somewhat below the optimum will result in less torque to be corrected by the tail rotor and, hence, a possible net saving in power. The book does not sufficiently emphasize this sort of thinking and tends to give the student too literal an approach to a design problem that in the end must always be a compromise. The curves of figure of merit on page 65 should fall off at the higher values of CT/σ.

The weakest parts of the book are those dealing with flight stability, vibrations, and the kinematics of blade motion. It is a shame that the authors have included only the age-old concept of constant shaft angular velocity with flapping considered as a forced vibration. This has always been a questionable physical approach, because the steady state flapping is of such a magnitude as to cause the exciting force to disappear. However, the final results are correct, of course. The lack of any reference to Arthur M. Young's work, "Two-Bladed Rotor," which appeared in the April, 1946, issue of *Aero Digest*, is a serious omission.

The chapters on stability and vibrations, although somewhat thin, and weak in English style, contain some good physical explanations that should be helpful to the student. It is a pleasure to read these serious attempts to describe just what is going on. However, it should be pointed out that there are basically two frequencies of motion in the helicopter, and there should be more emphasis on the factors that cause convergence and divergence of the oscillations.

The book is unfortunately marred by a rather poor job of proofreading. This will undoubtedly be corrected as readers report the numerous misprints to the authors. Fig. 2-10 is not only an insult to any mechanical intelligence, but it contains a bad booby trap for the student since the rotor responds 90° out of phase to the controls. If this diagram is worth including, it should be drawn in a thorough engineering fashion. It will doubtlessly be corrected in future editions.

The chapter on blade stall is exceptionally good and will be found useful by many designers, especially since it ends with lucid directions for application of the material. One could wish, however, that the authors had included the more recent work on the effects of compressibility. Perhaps this subject will provide the contents of an additional chapter in future editions.

The criticism is intended to be constructive. The authors have already filled a real need and are to be congratulated on their achievement. They have set a high standard in the purely aerodynamic part of the work and in most of the physical explanations. If in future editions the rest of the book can be brought up to this same high standard, it should be the leading text for years to come.

BARTRAM KELLEY
Chief Engineer, Helicopter Division
Bell Aircraft Corporation

The Principles of the Control and Stability of Aircraft

By W. J. Duncan. New York, Cambridge University Press, 1952. 384 pp., figs. $8.00.

Dr. Duncan's book represents an excellent summary of the theory of stability and control of aircraft from the aerodynamicist's point of view. This volume presents a well-chosen survey of the mathematical theory of aerodynamic stability, as well as the simple physical explanation of the various limiting cases such as (1) the rapid incidence adjustment, (2) the phugoid motion, (3) the pure rolling, etc. This approach is particularly useful to the engineer. As the author points out, the primary purpose of the theory of aircraft stability is (1) to provide a rational background for the analysis of actual occurrences, (2) to provide a rational basis for the planning of experiments and tests, thus securing economy of effort, and (3) to help the engineer to design more intelligently. The presentation by the author should be helpful for these purposes.

The book covers, only in outline form, the techniques for automatic stabilization of aircraft, the methods for the analysis of feedback networks such as automatic pilots, and the computation of the dynamic response of such systems. This is not a criticism of the book, since there are at present many excellent textbooks on the design of servosystems. The subject of the book is thus essentially the dynamic theory of one of the "black boxes" of the servo designer—the airplane. This book will be useful not only to the aerodynamicists, but also to the electrical and mechanical

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WILLIAM BOLLAY
Technical Director, Aerophysics Development Corporation

Gas Turbine Theory

By H. Cohen and G. F. C. Rogers. New York, Longmans, Green and Company, Inc., 1951. 291 pp., figs. $5.75.

Gas Turbine Theory by Cohen and Rogers is written for use as a text in the teaching of gas-turbine theory. The book is an orderly compilation of a series of lectures given by the authors at Bristol and Durham Universities and as a result is most complete in its context, although nothing new is presented. The work is limited to thermodynamic and aerodynamic theory, and practical aspects of design are avoided. The authors have drawn heavily on the published work of the early Power Jets and Royal Aircraft Establishment groups—i.e., Cheshire, Constant, Reeman, Hawthorn, et al.

The text loses some of its attractiveness for use in American schools because of the use of the mixed English Metric system as practiced in British gas-turbine industry, although this is a minor criticism. On the other hand, the work presented is far more basic than that in similar American texts, which is what would be expected of British authorship.

The data presented are compiled in nine chapters. After the introduction—which discusses the open cycle, use of the regenerator, intercooler, reheat compounding, and the closed cycle—the ideal cycle is covered in all of its forms. A few notes are presented on gas dynamics as related to flow in a gas turbine, which are followed by a chapter on the performance of practical gas-turbine cycles. The design of the major components is then discussed—i.e., the compressor, both axial and centrifugal, the turbine and the combustion sys-

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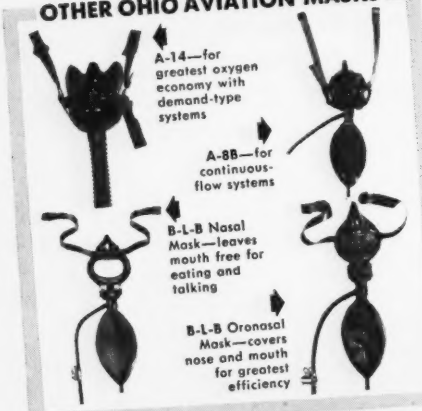
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tem, and, then, performance prediction of both aircraft and industrial sets. The book is concluded with a set of problems and answers relating to the material presented. It is noted that these problems and answers have appeared in examination papers in the universities where the authors have lectured.

S. T. ROBINSON
Engineer, Sanderson and Porter

Book Notes

ELECTRONICS

Electronic Measurements. Frederick Emmons Terman and Joseph Mayo Pettit. 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1952. 707 pp., figs. $10.

Since publication of the first edition in 1935, the revision has been so extensive and the scope so broadened that this is virtually a new book. It now covers measurement fundamentals in numerous fields beyond conventional radio, including television, radar and other pulsed systems, microwaves, and a diversity of techniques of value to engineers in other areas who may use electronics in their instrumentation.

The topics covered include wave guides and cavity resonators; standing-wave measurements; noise in amplifiers and receivers; frequency-modulation and television receivers; generation of special wave forms (pulses, square waves, sawtooth waves); generation of time delays; modern forms of vacuum-tube voltmeters; power measurement at microwave frequencies; antenna measurements into the microwave region, including directivity pattern, gain, and phase-front measurements; oscillators for laboratory signal sources covering the range from very low to microwave frequencies; transient and steady-state response of amplifiers and circuits; new oscilloscope technique; and stability of feedback amplifiers.

The present volume contains 449 figures and over 1,000 footnote references to the literature. The author and subject indexes are extensive. Both of the authors are associated with Stanford University, Frederick Emmons Terman as Professor of Electrical Engineering and Dean of the School of Engineering and Joseph Mayo Pettit as Associate Professor of Electrical Engineering.

Electronics for Communication Engineers. John Markus and Vin Zeluff. New York, McGraw-Hill Book Company, Inc., 1952. 610 pp., illus., diagrs., figs. $10.

This book brings to engineers 252 articles that appeared in *Electronics* magazine during the past 5 years on the topics of radio communication, radio broadcasting, television design, and radar design. It is a sequel to the authors' *Electronics for Engineers* and *Electronics Manual for Radio Engineers*, which reprinted material of the same type from earlier issues of the magazine.

The material has been edited and arranged under the following headings: Amplifiers, Antennas, Audio, Cathode-Ray Tubes, Components, Electronic Music, Filters, Measurements, Microwaves, Oscillators, Power Supplies, Propagation, Pulses, Receivers, Transmission Lines, and Transmitters. In addition to a detailed table of contents, the volume contains an index of subjects and an index of authors.

EQUIPMENT

ELECTRIC

Electric Machinery. A. E. Fitzgerald and Charles Kingsley, Jr. New York, McGraw-Hill Book Company, Inc., 1952. 702 pp., figs. $8.50.

This undergraduate textbook presents the basic principles common to all rotating electric machines

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The Naval Research Laboratory's Viking rocket research at White Sands Proving Grounds, N. M., hunts facts, figures and formulas in the upper atmosphere.

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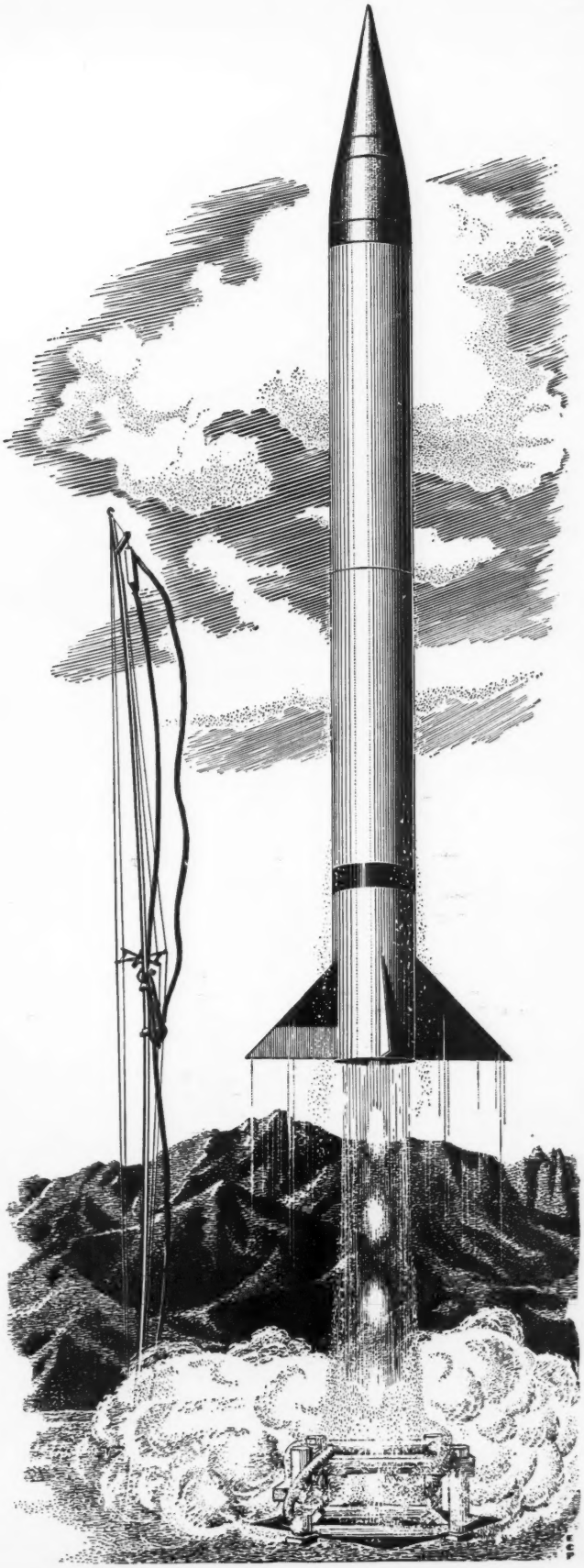

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as well as to many electromechanical-energy-conversion devices. The basic theory is applied to d.c., synchronous, polyphase induction, and single-phase machines, together with Amplidynes, Rototrols, and Selsyns. Transformers are included in the treatment, which ends with introduction to the machine transients and to the dynamics of electromechanical systems. Specific applications of principles and methods of analysis are illustrated by examples throughout the book. At the ends of chapters are given résumés of the material covered and problems for solution by the student. Some references are given in footnotes, and there is a lengthy subject index. The authors are Associate Professors of Electrical Engineering, M.I.T.

Chapter 1 examines the physical aspects of electromechanical energy conversion; the principles of this conversion are discussed in Chapter 2. Then follow chapters on the basic concepts of machine performance and machine analysis; d.c. machines are treated with respect to the analysis of their performance and their applications. The next two chapters, 7 and 8, are devoted to synchronous machines, the analysis of their performance, and the effects of saturation and salient poles. Chapters 9, 10, and 11 are concerned with polyphase induction machines, fractional horsepower a.c. motors, and control-type generators and self-synchronous machines. Electrical transients and the dynamics of electromechanically coupled systems form the subject matter of the two final chapters. An appendix on the basic theory of transformers is followed by a brief table of constants and conversion factors.

MATERIALS

Mechanical Properties of Metals at Low Temperatures. Proceedings of the NBS Semicentennial Symposium on Mechanical Properties of Metals at Low Temperatures Held at the NBS on May 14 and 15, 1951. (U.S., National Bureau of Standards, Circular No. 520.) Washington Superintendent of Documents, May 7, 1952. 206 pp., figs. $1.50.

Contents: (1) Recent European Work on the Mechanical Properties of Metals at Low Temperatures, N. P. Allen. (2) Manufacture of Steels for Low-Temperature Service, J. B. Austin. (3) Development and Application of Chromium-Copper-Nickel Steel for Low-Temperature Service, Walter Crafts and C. M. Offenhauer. (4) Tensile Properties of Copper, Nickel, and Some Copper-Nickel Alloys at Low Temperatures, Glenn W. Geil and Nesbit L. Carwile. (5) Application of Metals in Aircraft at Low Temperatures, J. B. Johnson and D. A. Shinn. (6) Properties of Austenitic Stainless Steels at Low Temperatures, V. N. Krivbok. (7) Dimensional Effects in Fracture, C. W. MacGregor and N. Grossman. (8) Mechanical Properties of High-Purity Iron-Carbon Alloys at Low Temperatures, R. L. Smith, G. A. Moore, and R. M. Brick. (9) Brittle Fractures in Ship Plates, M. L. Williams.

Metallurgy for Engineers; Casting, Welding, and Working. John Wulff, Howard F. Taylor, and Amos J. Shaler. New York, John Wiley & Sons, Inc., 1952. 624 pp., illus., diagrs., figs. $6.75.

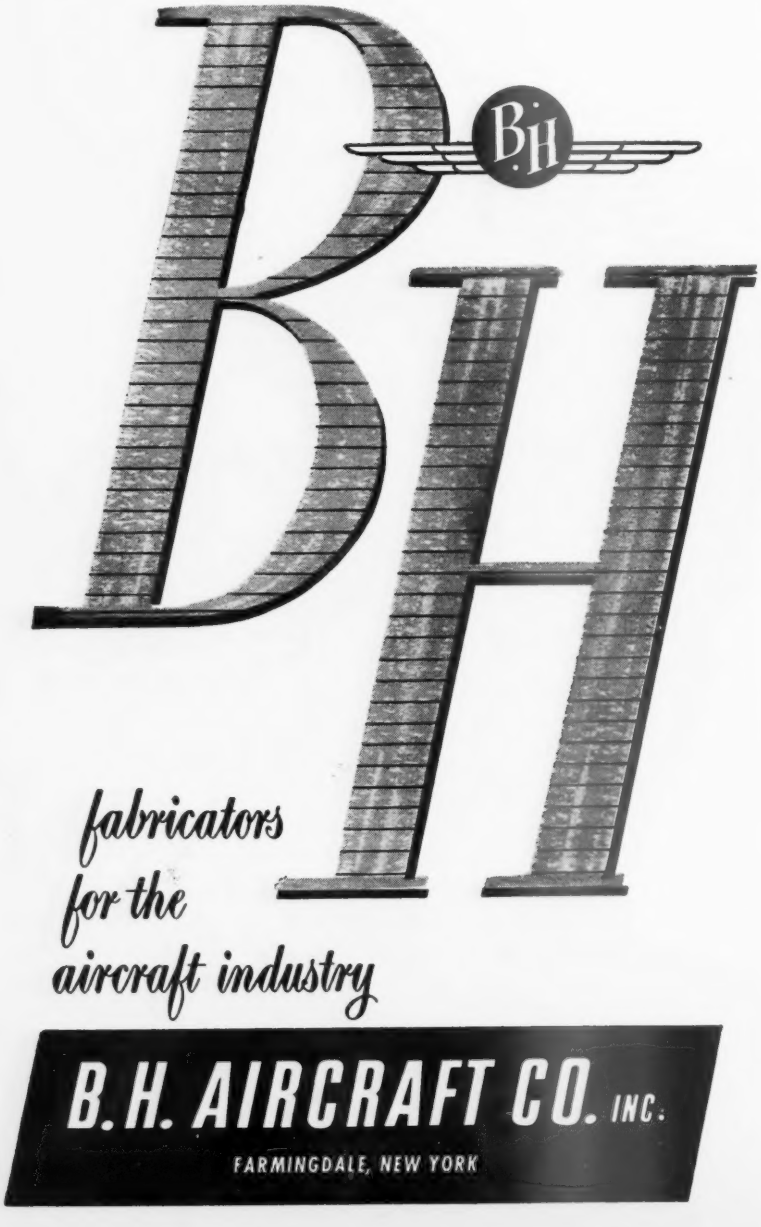
The material covered in *Metallurgy for Engineers* is a required part of the curriculum at M.I.T. for students in mechanical, aeronautical, and marine engineering, and in business and engineering administration. The book has been evolved during 5 years' experience in teaching metallurgy at M.I.T., where all three authors are on the staff of the Metals Processing Laboratory, Metallurgy Department.

The book is divided into two parts. The first half explains the concepts and principles which underlie metal processing from ingots to finished articles. The second half deals with the processes themselves. The point of view of the authors is that of the engineer rather than of the shop man. Many problems to be worked out by the student are included, and the many references to fuller treatments in the literature, concise definitions of technical terms, tables of technical data, and the arrangement of the subject index make the work of value as a reference book.

Contents: (1) Introduction to Engineering Metals. (2) Crystalline Structure and Properties of Metals. (3) Solidification of Pure Metals. (4) Impurity and Solubility. (5) Phase Equilibrium and Alloy Systems. (6) Alloy Systems of Limited Solid Solubility. (7) Industrial Non-Ferrous Alloys. (8) Alloys of Iron and Carbon. (9) Heat Treatment of Steel. (10) Heat-Treating Steel. (11) Methods for Determining Mechanical Properties of Metals. (12) Mechanism of Deformation and Effects of Deformation of Metals. (13) Electrical and Magnetic Properties of Metals. (14) Corrosion. (15) Introduction to Sand Casting Processes. (16) Casting Processes Other Than Sand Casting. (17) The Ingot as a Casting. (18) Melting—Heat Flow—Gases in Metals. (19) Casting Defects—Inspection Methods—Casting Design. (20) Gating and Risering. (21) Powder Metallurgy. (22) Welding. (23) Arc-Welding Processes. (24) Gas Welding, Thermit Welding, and Metalizing. (25) Pressure Welding Processes. (26) Brazing and Soldering. (27) Metal Working by Compression Processes. (28) Stretching, Shearing, and Bending Processes. (29) Metal Cutting.

Corrosion Testing Procedures. F. A. Champion. New York, John Wiley & Sons, Inc., 1952. 369 pp., illus., diagrs., figs. $6.25.

The procedure described in this comprehensive handbook should be of interest to those concerned with practical problems in the corrosion of metals in service and in the production of metals of adequate corrosion resistance. The course followed in this work has been to divide the text into stages and then to describe separately the various alternative procedures for each stage, as follows: (1) the choice and preparation of metal and corrosive; (2) exposure in laboratory field of service tests; (3) preparatory cleaning of specimens; (4) examination of specimens or corrosive for the effects of corrosion (considered separately are



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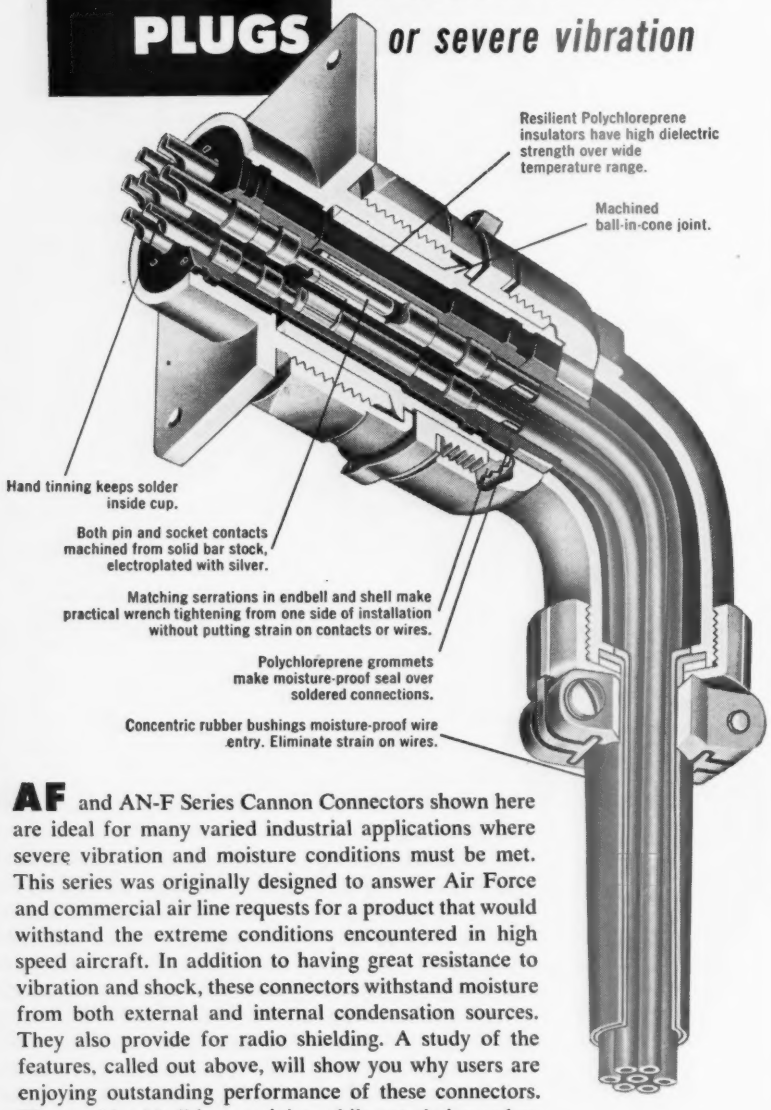
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other measurements indicating the tendency to corrode rather than the effects of corrosion, and special tests); and (5) expression and interpretation of results with particular reference to the form of the corrosion-time curve. A total of 793 references is given at the ends of chapters, and the book is provided with extensive author and subject indexes.

Contents: Chapter 1, Introduction. Chapter 2, Metal Factors. Chapter 3, Corrosion Media. Chapter 4, Laboratory Exposure Conditions. Chapter 5, Laboratory Conditions for Conjoint Action. Chapter 6, Field and Service Tests. Chapter 7, Cleaning of Specimens After Corrosion. Chapter 8, Assessment of Effects on the Metal. Chapter 9, Assessment of Effects on the Environment. Chapter 10, Ancillary Observations. Chapter 11, Special Tests. Chapter 12, Expression and Interpretation of Results.

SCIENCES, GENERAL

MATHEMATICS

Approximate Methods of Higher Analysis (Priblizhennye Metody Vysshego Analiza). L. V. Kantorovich and V. I. Krylov. 3rd Ed. Moscow, State Publishing House of Technico-Theoretical Literature, 1950. 695 pp., figs. (In Russian.)

This treatise for mathematical physicists gives particular emphasis to the approximate methods of solution that have been developed in the Soviet Union during the past 30 years. Its scope embraces older methods, as well as the network and variational methods, which were developed at the beginning of this century. The first edition appeared in 1936 and was reissued in 1941 in enlarged and revised form. Worked-out examples show application of the methods discussed, and there are numerous footnote references to fuller treatments in published literature. The lack of a subject index is somewhat compensated for by the detailed table of contents.

The work is divided into seven sections, as follows: Section 1, Methods Based on the Presentation of the Solution in the Form of an Infinite Series. Section 2, Approximate Solution of Fredholm's Integral Equations. Section 3, Method of Networks. Section 4, Variational Methods. Section 5, Conformal Transformation of Regions. Section 6, Principles of Application of Conformal Transformation to the Solution of Fundamental Problems for Conical Regions. Section 7, Schwartz's Method.

VIBRATION

Theory of Vibrations for Engineers. E. B. Cole. 2nd Revised Ed. London, Crosby Lockwood & Son Ltd.; New York, The Macmillan Company, 1950. 334 pp., figs. $5.00.

Following a brief introduction defining the units used by the author, there are three chapters dealing with simple harmonic motion and the natural vibrations of systems having one or several degrees of freedom. Damped vibrations, natural vibrations of heavy shafts, forced vibrations in general, and multiple systems are then considered. Chapter 8 is concerned with practical applications such as the engine indicator, vibration recorders, the fatigue testing machine, and balancing machines for rotors. The remaining chapters cover the topics of engine vibration, elimination and absorption of vibration, dynamic loads and waves, transverse vibration of beams, and the whirling of shafts.

The Appendix treats of the undamped vibration absorber and the whirling of a De Laval rotor. Throughout the text, liberal use has been made of diagrams and figures. Many testing devices have been described, and a large number of examples has been worked out. Major attention is given to the problems of high-speed propulsion and power-plant machinery. The author is Lecturer in Mechanical Engineering at the University of Liverpool.

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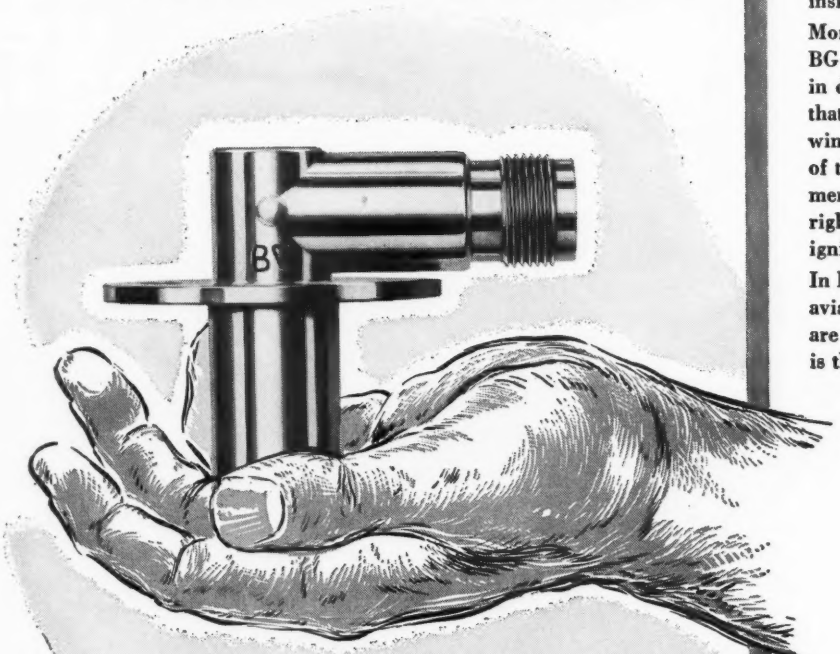

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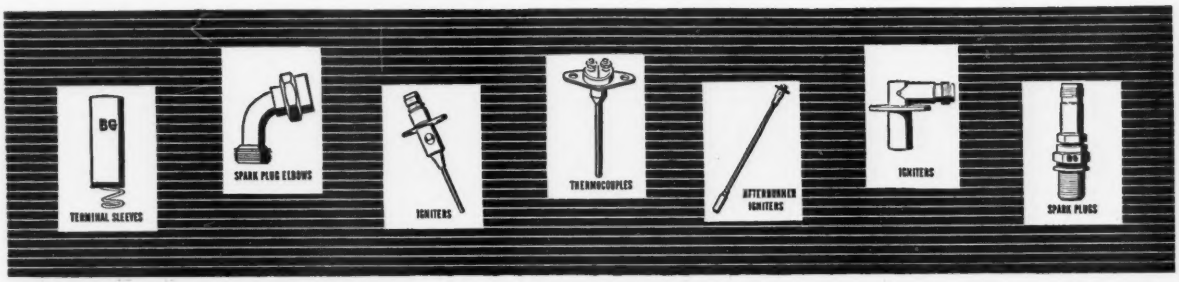

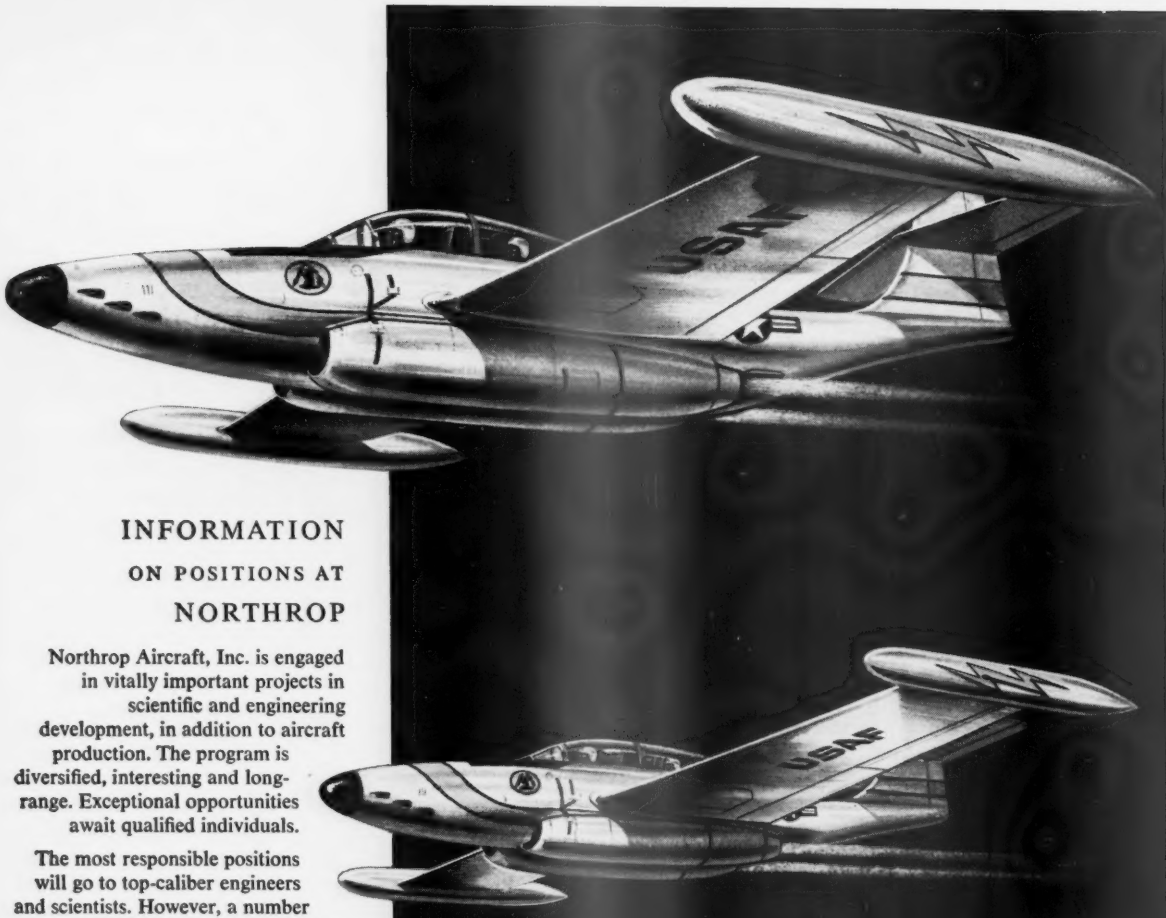

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Professors—The Hebrew Institute of Technology, Haifa, Israel, proposes to appoint two professors of aeronautical engineering, one with special qualifications in airplane structures and dynamics. Applicants should have first-rate professional and academic qualifications, be willing to integrate themselves into the life of the country, and, in due course, to teach in Hebrew. Applications with full details should be sent, for transmission to Haifa, to The American Technion Society, 80 Fifth Ave., New York 11, N.Y. Those accepted will be working with Dr. Sidney Goldstein.

Engineers, Technologists, Physicists, Physiologists, Metallurgists—The Naval Air Material Center located in the U.S. Naval Base at the extreme south end of Broad Street in Philadelphia, Pa., has vacancies in the above positions for qualified eligibles. These vacancies are at grade GS-5 to GS-12 level with salary ranging from $3,410 to $7,040 per annum. The Naval Air Material Center (the air center is divided into three major branches—the Naval Aircraft Factory, the Naval Air Experimental Station, and the Naval Auxiliary Air Station) is engaged in research (applied), development, manufacture, modification, test evaluation and overhaul of aircraft, aircraft components, and aeronautical materials, including launching and arresting devices. At this activity, we have the job of finding the answers to a never-ending series of problems which involve the whole field of aeronautical sciences. Interested persons should file an application for Federal employment, Standard Form 57, with the Industrial Relations Department, Naval Air Material Center, Naval Base, Philadelphia 12, Pa. Applications may be obtained from the Industrial Relations Department, Naval Air Material Center, or any first- or second-class Post Office or from any Civil Service Regional Office.

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421. Aeronautical Engineer—Opening for instructor in airplane design and related subjects in aeronautical engineering curriculum. Excellent opportunity for qualified man. Reply should cover engineering education and experience. California location (Los Angeles area).

415. Instructor—Aeronautical Engineering Department of a large eastern university to teach undergraduate courses in fluid mechanics and aeronautical laboratory. Applicant should have master's degree from recognized university or equivalent experience in the aeronautical field. Opportunity for graduate work and research in structures or aerodynamics. Large subsonic and 6-in. supersonic tunnels in operation. Salary $4,000 for the academic year.

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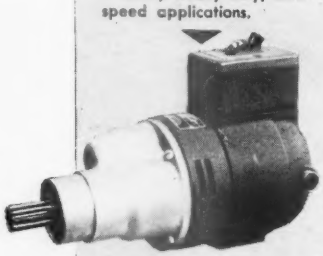

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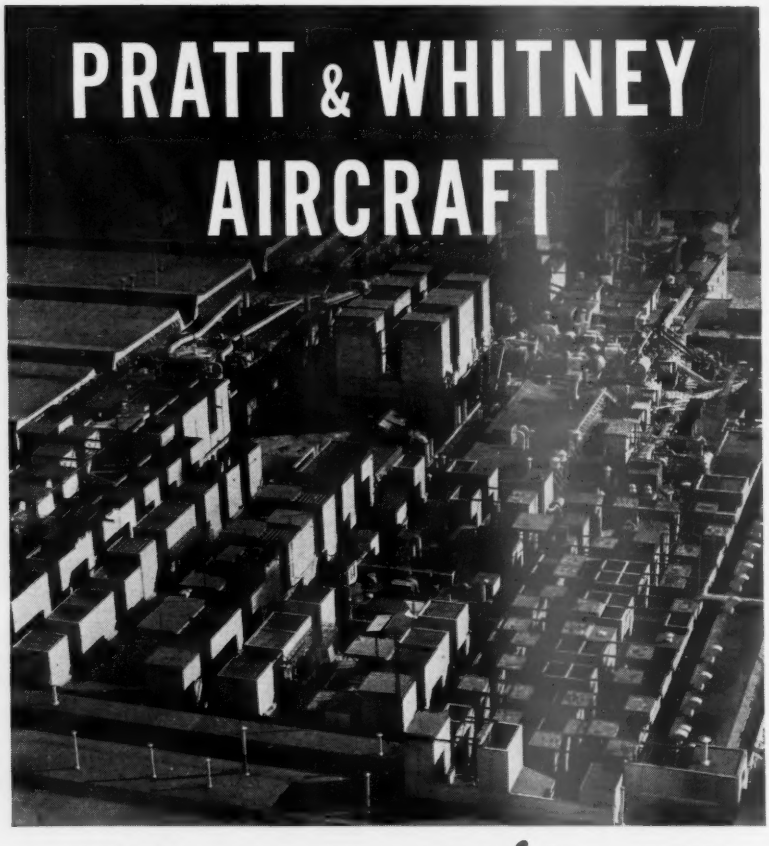

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406. Senior Missiles Aerodynamics Research Engineer—Ph.D. in A.E. to perform and/or supervise guided missile aerodynamics work concerned with development of improvements in design and in analytical and/or test techniques. Desirable additional qualifications should include experience in missile or aircraft aerodynamics, preferably in supersonic aerodynamics, or in related thermodynamic or fluid mechanics work. Salary commensurate with experience. Location Midwest.

405. Senior Missiles Propulsion Research Engineer—Ph.D. in A.E., M.E., Physics, or Ch.E. with thesis in fields of propulsion or combustion. Will perform and/or supervise guided missile aerodynamics work concerned with development in design and in analytical and/or test techniques. Desirable additional qualifications should include 1 to 4 years' experience in missile or aircraft propulsion, or in combustion work, or in related thermodynamic, fluid mechanics, or aerodynamics work. Salary commensurate with experience. Location Midwest.

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420. Engineer—B. of M.E., Gas Turbine Project Engineer in Government for 1 year. Previous engineering background in aircraft tooling, welding, and process planning for 2 years. Also practical experience as toolmaker. Desires permanent position of increasing responsibility in gas-turbine or allied industry. Age 29.

419. Aeronautical Engineer—M.E. and M.S., 23 years' experience with large aircraft companies in all phases of stress analysis, aerodynamics, flight testing, and dynamics analysis. Would like connection with small aircraft concern in executive or staff capacity in charge of similar type of work.

418. Research and Development Engineer—Extensive background. Would like to consult on aerodynamic instrumentation for wind tunnel, flight test, and ballistics, of missiles and rockets. Has made significant developments. Design, construction, and testing of prototypes can be furnished.

417. Independent Engineer—With many years' experience in aeronautics and research. Would like to contact progressive organization with product, idea, or territory available for Southern California or perhaps West Coast. Wide contacts and background in aircraft, guided missile, rocket and ballistics engineering, and research circles. Can provide staff or organization for sales, engineering, consulting, or technical representation.

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402. Aeronautical Engineer—Nine years' engineering experience in aeronautical field. Formerly with U.S. major air line as modification and service engineer handling aircraft structures and fluid systems. Also had experience as field service engineer with leading heavy aircraft manufacturer. Most recently connected with manufacturer of supersonic aircraft and guided missiles with design experience on rocket-engine installation structures and servomechanisms.

Aeronautical Reviews

(*Concluded from page 105*)

A New Method for Determining the Static Temperature of High-Velocity Gas Streams. J. A. Clark and W. M. Rohsenow. *American Society of Mechanical Engineers, Transactions*, Vol. 74, No. 2, February, 1952, pp. 219–228, illus. 15 references.

Review of the general problem of measuring the static temperature of high-velocity gases flowing subsonically at any level of temperature; design and experimental data on an instrument for measuring the static temperature; thermodynamic considerations.

On the Convergence of Numerical Solutions of the Heat-Flow Equation. F. B. Hildebrand *Journal of Mathematics and Physics*, Vol. 31, No. 1, April, 1952, pp. 35–41. 3 references.

Heat Flow in Composite Slabs. E. Mayer. *American Rocket Society, Journal*, Vol. 22, No. 3, May–June, 1952, pp.150–158, illus. 5 references. Mathematical presentation of the temperature transients in a composite slab corresponding to the heat-transfer conditions in a rocket motor.

Letters to the Editor: Heat Conduction Along an Exponential Bar. John W. Miles. *Journal of Applied Physics*, Vol. 23, No. 3, March, 1952, p. 372. Solution of an equation for one-dimensional diffusion, specifically heat conduction, along a tube of exponentially varying cross section.

Relaxation of Stress in a Heat-Exchanger Tube of Ideal Material. E. A. Davis. *American Society of Mechanical Engineers, Transactions*, Vol. 74, No. 3, April, 1952, pp. 381–385, illus. 1 reference.

Analytical solutions for the relaxation of an elastico-viscous tube in a rigid tube sheet in both plane stress and a modified plane strain; effect of reloading tensile specimens in relaxation.

Analysis of Stresses and Displacements in Heat-Exchanger Expansion Joints. Glenn Murphy. *American Society of Mechanical Engineers, Transactions*, Vol. 74, No. 3, April, 1952, pp. 397–402, illus. 1 reference. A procedure, using the method of successive approximations, for analyzing the stresses and displacements in an expansion joint.

High Temperature Propellant Reactions. F. E. Osborne. *Aircraft Engineering*, Vol. 24, No. 279, May, 1952, pp. 134–137. 8 references. Determination of the thermodynamic properties of the gaseous products of combustion for use in heat-engine calculations.

Water-Borne Aircraft (21)

The Flying-Boat and Its Place in Aviation. Frederick Bowhill. *Airports & Air Transportation*, Vol. 5, No. 93, March-April, 1952, pp. 316–318.

The commercial possibilities and advantages of flying boats; problems in establishing and maintaining bases; present British operations and routes; comparative size of land and water airports.

Wind Tunnels & Research Facilities

Gas-Turbine Research at Bristol. *The Aeroplane*, Vol. 82, No. 2129, May 9, 1952, p. 570, 571–576, illus., cutaway drawings. *Flight*, Vol. 61, No. 2259, May 9, 1952, pp. 559–563, illus., cutaway drawing.

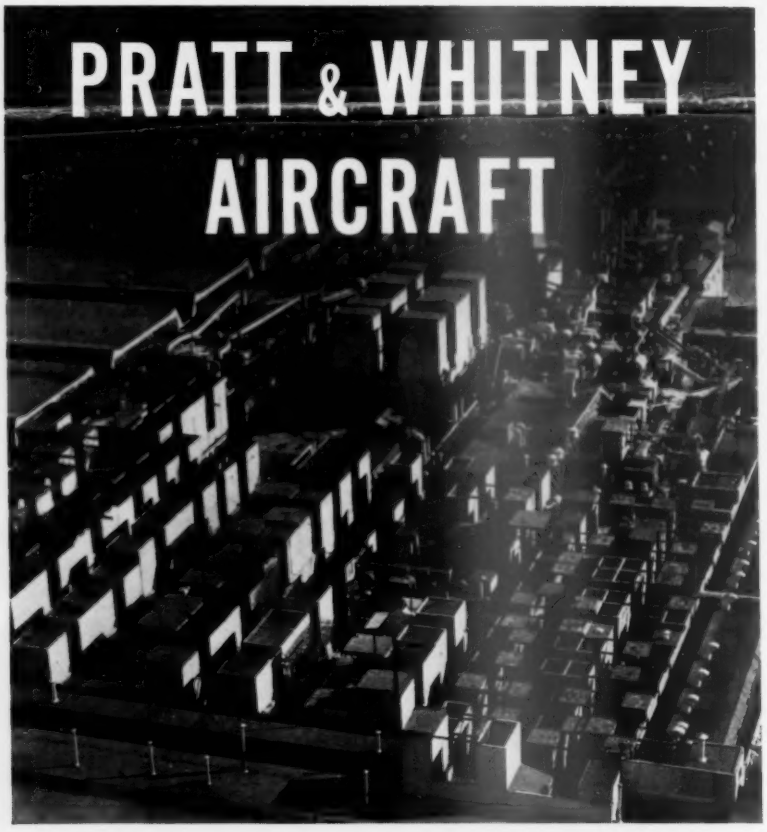
Equipment, layout, and testing methods used in Bristol Aeroplane Co.'s gas-turbine research facilities that include laboratories for component and materials testing, a compressor and turbine test house with 26,300 installed hp., a paired test-bed for full-scale engine studies, and the related power and control equipment. The test facilities can accommodate the largest of today's jet engines and the larger ones that will be built in the future.

New Valve Design to Throttle a Hurricane. *Mechanical Topics*, Vol. 13, No. 4, 1952, p. 7, illus.

Design and application of the Stressed Seal butterfly valve developed by the Henry Pratt Co. for controlling air currents in supersonic wind tunnels at temperatures ranging from −65° to 750°F.

Visualization of Flow Fields by Use of a Tuft Grid Technique. John D. Bird. *Journal of the Aeronautical Sciences*, Vol. 19, No. 7, July, 1952, pp. 481–485, illus. 5 references. Apparatus and procedure of the grid tuft technique for obtaining a physical picture of the flow field behind a wing or a wing-body combination.

Tank Test of Radiosonde Ventilator Tubes. M. Sanuki, N. Tsuda, and A. Kusano. *Papers in Meteorology and Geophysics*, Vol. 2, No. 2, June, 1951, pp. 196–204, illus. 3 references. Design features and equipment of a towing water tank, experimental techniques, and results of tests in the tank of radiosonde-ventilator-tube performance.



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cuitry or photoelectric devices. Salary commensurate with experience. Location Midwest.

407. Senior Missiles Dynamics Research Engineer—Ph.D. in M.E., Physics, or Applied Mechanics to develop and exploit advanced techniques for use in the dynamic analysis, synthesis, and test of complete guided missiles. Desired additional qualifications should include 1 to 4 years' experience in the field of automatic controls, flutter and vibration, aerodynamics, structures, hydraulics, or electronics. Salary commensurate with experience. Location Midwest.

406. Senior Missiles Aerodynamics Research Engineer—Ph.D. in A.E. to perform and/or supervise guided missile aerodynamics work concerned with development of improvements in design and in analytical and/or test techniques. Desirable additional qualifications should include experience in missile or aircraft aerodynamics, preferably in supersonic aerodynamics, or in related thermodynamic or fluid mechanics work. Salary commensurate with experience. Location Midwest.

405. Senior Missiles Propulsion Research Engineer—Ph.D. in A.E., M.E., Physics, or Ch.E. with thesis in fields of propulsion or combustion. Will perform and/or supervise guided missile aerodynamics work concerned with development in design and in analytical and/or test techniques. Desirable additional qualifications should include 1 to 4 years' experience in missile or aircraft propulsion, or in combustion work, or in related thermodynamic, fluid mechanics, or aerodynamics work. Salary commensurate with experience. Location Midwest.

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420. Engineer—B. of M.E., Gas Turbine Project Engineer in Government for 1 year. Previous engineering background in aircraft tooling, welding, and process planning for 2 years. Also practical experience as toolmaker. Desires permanent position of increasing responsibility in gas-turbine or allied industry. Age 29.

419. Aeronautical Engineer—M.E. and M.S., 23 years' experience with large aircraft companies in all phases of stress analysis, aerodynamics, flight testing, and dynamics analysis. Would like connection with small aircraft concern in executive or staff capacity in charge of similar type of work.

418. Research and Development Engineer—Extensive background. Would like to consult on aerodynamic instrumentation for wind tunnel, flight test, and ballistics, of missiles and rockets. Has made significant developments. Design, construction, and testing of prototypes can be furnished.

417. Independent Engineer—With many years' experience in aeronautics and research. Would like to contact progressive organization with product, idea, or territory available for Southern California or perhaps West Coast. Wide contacts and background in aircraft, guided missile, rocket and ballistics engineering, and research circles. Can provide staff or organization for sales, engineering, consulting, or technical representation.

414. Engineering or Research Executive—Many years' experience with leading company. Offering an outstanding record in design and research, allied to demonstrated administrative ability. Familiar with subsonic and supersonic design. Airplanes, missiles, dynamic problems, guidance, servomechanisms, and flight testing.

413. Mechanical Engineer—Age 35. B.S. and M.S. in M.E. Eleven years' rounded experience in aircraft power-plant installation analysis, supercharger performance analysis, gas turbine compressor and turbine design, combustion phenomena, and industrial heat transfer. Extensive supervisory experience administering engineering department. Desires responsible position in expanding organization. Prefers eastern location.

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410. Aeronautical Engineer—(B.S. 1948). Age 25, single. Currently serving in Army under Special Professional Personnel Program. Army experience: Eight months with Project Investigation Section, Ordnance Guided Missile Center; aided in developing nomograms for first approximations of missile performance. Twelve months with Army Aircraft National Maintenance Point; helped establish procedures for use of IBM equipment in the preparation of Army Supply Catalogs and helped to develop procedures for maintenance of Army liaison aircraft and helicopters. Civilian experience includes 18 months power-plant installation design, 6 months flight-test work. Has private pilot's license, Aircraft and Engine Mechanic's ratings. Would like position with small, expanding company, preferably in the guided missile or helicopter fields. Available January 1, 1953.

409. Plant Manager—Twenty years' aircraft and allied experience. Last position 7 years' full-control manufacturing of large instrument company. East Coast preferred. Offer with salary in first letter appreciated.

402. Aeronautical Engineer—Nine years' engineering experience in aeronautical field. Formerly with U.S. major air line as modification and service engineer handling aircraft structures and fluid systems. Also had experience as field service engineer with leading heavy aircraft manufacturer. Most recently connected with manufacturer of supersonic aircraft and guided missiles with design experience on rocket-engine installation structures and servomechanisms.

Aeronautical Reviews

(*Concluded from page 105*)

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The commercial possibilities and advantages of flying boats; problems in establishing and maintaining bases; present British operations and routes; comparative size of land and water airports.

Wind Tunnels & Research Facilities

Gas-Turbine Research at Bristol. *The Aeroplane*, Vol. 82, No. 2129, May 9, 1952, p. 570, 571–576, illus., cutaway drawings. *Flight*, Vol. 61, No. 2259, May 9, 1952, pp. 559–563, illus., cutaway drawing.

Equipment, layout, and testing methods used in Bristol Aeroplane Co.'s gas-turbine research facilities that include laboratories for component and materials testing, a compressor and turbine test house with 26,300 installed hp., a paired test-bed for full-scale engine studies, and the related power and control equipment. The test facilities can accommodate the largest of today's jet engines and the larger ones that will be built in the future.

New Valve Design to Throttle a Hurricane. *Mechanical Topics*, Vol. 13, No. 4, 1952, p. 7, illus.

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